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THE HALOID COMPANY

(UNDER PRIME CONTRACT NO. W-36-039 sc-36351 WITH THE U. S. ARMY SIGNAL CORPS ENGINEERING LABORATORIES, BRADLEY BEACH, N. J.)

CONTINUOUS-TONE ELECTROSTATIC ELECTROGRAPHY

BATTELLE M

7th QUARTERLY REPORT
SIGNAL CORPS CONTRACT NO. W36-039-sc-36851
Period 15 Dec., 1949 to 15 Mar., 1950

ELECTROSTATIC ELECTROPHOTOGRAPHY

THE HALOID COMPANY
ROCHESTER, N. Y.

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Further information concerning this project may be obtained from Mr. Steven Levinos, Chief, Chemical and Methods Section, Photographic Branch, SSL, Fort Monmouth, N. J. Phone Eatontown 3-1060, extension 1612.

A-3262

BATTELLE MEMORIAL INSTITUTE
INDUSTRIAL AND SCIENTIFIC RESEARCH
COLUMBUS 1, OHIO

March 20, 1950

Dr. John Dessauer
The Haloid Company
Rochester 3, New York

Dear Dr. Dessauer:

We are enclosing 56 copies of Quarterly Progress Report No. 7 on Continuous-Tone Electrophotography. This report covers the work for the three-month period from December 15, 1949, to March 15, 1950.

Data giving the engineering design specifications for the process as it is carried out at present have been obtained. Work consisted of detailed information on the geometry and spacing of parts, voltages to provide, plate preparation data, etc. Further work is being done to determine more exactly the operational data, such as latitude of exposure and best charging and development conditions for different subjects having a variety of brightness and contrast ranges.

A new method of development utilizing a spray of dry powder, different from liquid spray previously reported, has produced pictures of very fine grain and pleasing tonal values.

Adhesive-transfer and adhesive-fixing techniques have proved very successful. These completely eliminate electrical breakdown during transfer which was a difficulty encountered with electrostatic transfer.

Very truly yours,

L. E. Walkup

Lewis E. Walkup
Assistant Supervisor
Graphic Arts Research Division

LEW:swr
Enc. (56)

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QUARTERLY PROGRESS REPORT NO. 7
(December 15, 1949, to March 15, 1950)

on

CONTINUOUS-TONE ELECTROSTATIC ELECTROGRAPHY

to

THE HALOID COMPANY

(Subcontract Under Signal Corps Prime Contract
No. W36-039 sc-36851)

(Department of the Army Project: 3-99-04-052)

(Signal Corps Project: 195 B)

by

R. M. Schaffert, D. T. Williams, and L. E. Walkup

OBJECTIVE OF RESEARCH: To evolve an electrostatic electrographic system capable of reproducing continuous-tone photographs.

BATTELLE MEMORIAL INSTITUTE

March 15, 1950

TABLE OF CONTENTS

TABLE OF CONTENTS - Continued

QUARTERLY PROGRESS REPORT NO. 7
(December 15, 1949, to March 15, 1950)

on

CONTINUOUS-TONE ELECTROSTATIC ELECTROGRAPHY

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R. M. Schaffert, D. T. Williams, and L. E. Walkup

March 15, 1949

SUMMARY

This report covers experimental work on continuous-tone electrophotography from December 15, 1949, to March 15, 1950.

Work on this project for the past quarter included both a continuation of research on the over-all electrophotographic process and the establishment of detailed engineering information on the process as it stands at present. The establishment of engineering information was necessary to allow the completion of the design of an electrophotographic camera. This information was submitted to The Haloid Company on February 1, 1950.

The detailed investigation of a large number of variables in the process was necessary to provide the necessary data for camera design. The work is divided into five broad groups, namely: (1) plate preparation techniques and plate characteristics, (2) plate sensitizing technique and potentials to be used, (3) factors concerned with plate exposure, (4) plate-development requirements and control, and (5) transfer and fixing methods.

In group number one, a brass-backed, selenium-coated plate is recommended, the coating being 50 microns in thickness. Such a plate is capable of sustaining 275 volts without suffering electrical breakdown and, thereby, is capable of producing images without powder-deficient areas and excessive graininess. Further, these plates have exceptionally slow potential-decay rates in the dark and have adequate light sensitivity to achieve ASA speeds in the range of 12 to 25 in daylight.

In group two, concerning plate sensitizing techniques, a study was made of the best available model of a potential-control, charging unit to determine the effect of its voltage characteristics and geometry on the charge produced on electrophotographic plates. The variables of corona voltage, grid voltage, grid-to-plate spacing, and rate of traverse of the plate under the charging unit were investigated. These factors are not so critical in affecting plate potential as to offer serious control problems. A brief series of prints was made to determine the effect of different initial plate potentials on image density. It was found that the plate potential from one charging to another can vary over wide limits (approximately a 100-volt range from 150 volts to 250 volts or more) with very little change in image density.

In group three, involving factors concerned with plate exposure, only one test concerned with exposure alone was carried out. This was to study the effect of extended time intervals between sensitizing and exposing the plate and between exposing and developing the plate. A time interval of 20 minutes, either before or after exposure, can be expected to have very little effect on image density or tone quality.

In group four, involving development requirements and control, several different experiments were conducted. The most advantageous spacing of wires in the development grid was found to be about 50 wires per inch, and the best grid-to-plate spacing was found to be about 0.050 inch. Tests on powder boxes show that the most dependable powder-cloud generator, found to date, is comprised of one brush, having a single row of bristles, mounted to reciprocate in a box, the dimensions of which are 5 by 6 by 2-1/2 inches. This powder-cloud device is capable of producing repeatedly electrophotographic prints of acceptable quality. It is possible to make 10 or 12 prints from such a box, using a single 65-gram developer charge (Al-5 powder and glass bead carrier) before a decrease in image density becomes noticeable. A brief study of development-grid cycling, or grid voltage adjustment during development, revealed that improved tonal rendition can be accomplished in this way, but that the results of such a procedure are critically dependent on exposure. A series of 24 prints, made using the brush-box cloud generator with a single charge of developer, showed that the variation in density of a print of a given subject is expected to be plus or minus 0.1 density unit at a density of 0.9.

In group five, concerned with transfer and fixing methods, it is shown that the adhesive-tape method of transferring the powder image from the electrophotographic plate to the white-backed print is definitely superior to the electrostatic transfer method. Adhesive transfer utilizes a white, opaque, pressure-sensitive tape which is pressed firmly against the powder image on the plate by means of rubber rollers. The tape is removed from the plate and the transferred image covered with a transparent adhesive tape to protect it and make it permanent. The tapes available for this use at the present time, while not ideally suited to the purpose, will produce prints of very good quality. At our request, tapes which should be more suitable are being made in experimental lots by the supplier of the tapes used at present.

Three methods of controlling the polarity of the powder particles in the cloud near the plate surface were investigated. The most successful method uses a grid held at high negative potential which attracts the undesired positively charged particles and thus removes them from the cloud. Experiments on such a sorting grid have been reported previously, but a comparison with other methods of accomplishing the same end result was not made in the previous work.

A method of spraying dry developer powders has been used successfully to produce electrophotographic prints of finer grain than those obtained with the powder-cloud boxes of the agitator or brush type. The rendition of tone with powder spray is also superior to that produced by the agitator or brush-type powder-cloud box and approaches the over-all quality produced by liquid-spray techniques. This powder-spray method has not yet been applied to development in an enclosed box, but certain modifications of the method will probably be adaptable to an enclosed box.

A study of one step in the cleaning technique for the brass plates prior to coating with selenium has shown that the petroleum fraction of the Glass Wax is responsible for the good results in this application. Coating the brass plate with a very thin layer of paraffin instead of scrubbing the plate with Glass Wax has the same beneficial effect on electrical characteristics of the electrophotographic plate.

Graininess in prints made from phosphor-coated plates is directly dependent upon particle size in the phosphor. A decrease in particle size from 75 to 5 microns produces a definite improvement in grain quality. Picture quality and accepted potential are directly dependent upon the thickness of the phosphor layer up to a thickness of 0.007 inch (175 microns). A further increase in thickness does not further improve print quality or increase the accepted potential (under the charging conditions used). Phosphor plates made by spray, dip, and doctor-blade techniques have electrical and print-making properties which essentially are the same.

FUTURE WORK

Process details which involve the operation of the electrophotographic camera will receive primary attention. Work will also be done with the brush-type development box to improve the homogeneity of the cloud and reduce the number of agglomerated powder particles produced.

Research on the broader aspects of continuous-tone electrophotography will continue insofar as such activity does not delay the work more closely connected with camera design and operation.

The following specific points concerning process details will receive particular attention:

1. Improve uniformity of powder-cloud density and reduce number of agglomerated particles in the cloud.

2. Improve fidelity of density reproduction.

3. Study the process conditions to determine the effective plate speed and optimum exposure using different plate potentials, a variety of exposure conditions and different modifications of the brush-type development box.

4. Improve the materials and techniques used in the adhesive transfer and fixing operations.

Various combinations of brush designs, bristle types, stroke lengths and frequencies, types of developer powders and baffles will be investigated. The effects of cloud-generator design, powders used, plate potentials and exposure conditions on tone, or density, rendition will be studied. The effect of different initial plate potentials and a variety of exposure conditions, including wide ranges of brightness and contrast, on effective plate speed and image quality will also be investigated. Adhesive transfer tapes with less tack and with smoother adhesive surfaces will be procured and tested.

The feasibility of adapting the powder-spray technique to development in a totally enclosed box will be investigated. Both the powder-spray and liquid-spray development methods will be refined to improve image quality and to simplify the apparatus and its operation, so that they may be presented at the termination of the contract period as alternative development techniques.

A study of the properties of phosphor plates will continue at a reduced rate of effort. Some work will also be done on the determination of particle charge and density in the powder cloud.

PUBLICATIONS AND REPORTS

(None)

ENGINEERING INFORMATION FOR DESIGN OF ELECTROPHOTOGRAPHIC CAMERA

In order to have a complete and working electrophotographic camera before the termination date of this contract (June 14, 1950), the date of February 1, 1950, was set as the time when the necessary engineering information on the process, as it stands at present, should be sent to The Haloid Company for use in the final camera design. This detailed engineering information has been assembled and was reported to representatives from The Haloid Company at the time of their visit to Battelle on February 1, 1950. This information was also submitted, in a letter, to Dr. Dessauer of The Haloid Company. A copy of this letter is included in the Appendix of this report.

Much of the information given in this letter to Dr. Dessauer has been reported in previous Quarterly Progress Reports. However, part of the information resulted from recent work aimed at completing the basic engineering information necessary to construct an electrophotographic camera. This work is described in the following sections, along with other experimental work completed.

EXPERIMENTAL WORK ON POWDER-CLOUD BOXES

H. E. Carlton, E. C. Ricker, and O. A. Ullrich

Agitators for the Powder-Cloud Box

Several designs of agitators have been made and tested in the powder-cloud box. An agitator consisting of a single brush which brushes over a coarse screen fastened to the bottom of the box has produced the best and most dependable cloud for developing continuous-tone electrophotographic images. A developer consisting of uncoated glass beads and A1j powder has been used successfully in this brush-type box. Other methods of producing a cloud in the powder box, including cloth and cotton impregnated with powder, were tried without success.

Box and Agitator Design

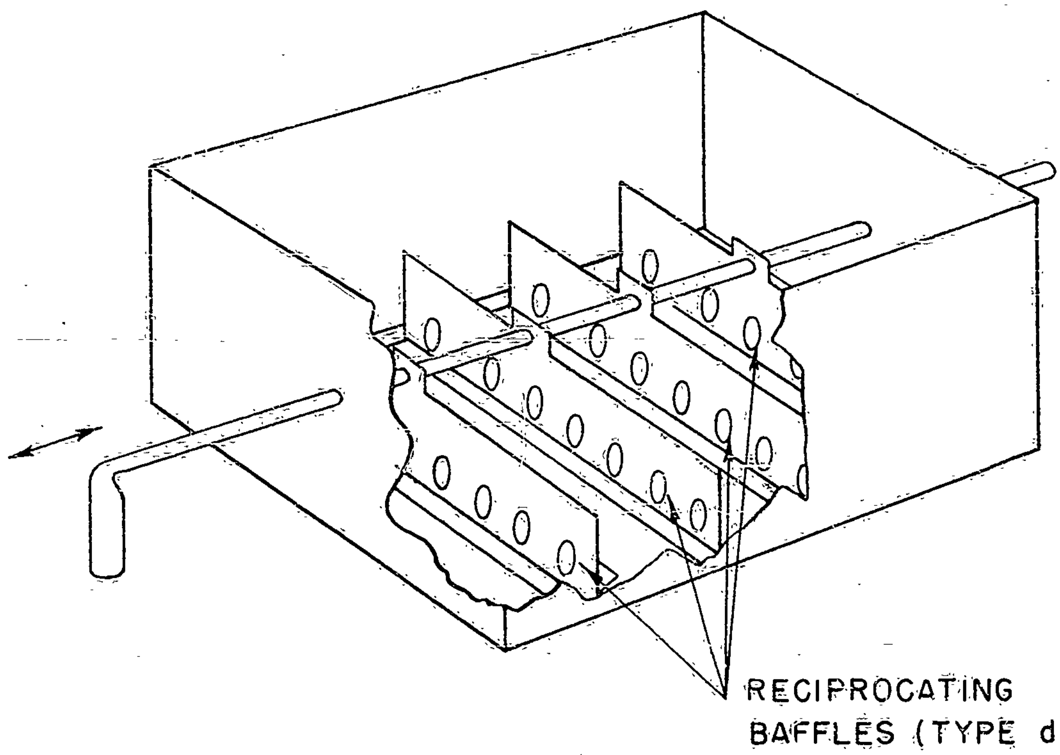
The powder-cloud box used for this work was constructed of brass sheet and had the following dimensions: 5 inches wide, 6 inches long and either 1.5 inches or 2.5 inches deep. Several designs utilized variously shaped baffles which were moved through the powder. These baffles were mounted on a rod 1/8 inch in diameter which passed through holes in the ends of the box. Figure 160 shows a cutaway view of the box with baffles mounted on the reciprocating rod. Also shown in this figure are the cross-sectional shapes of the various types of baffles and brushes used.

A development grid was used which consisted of wires 0.003 inch in diameter, spaced 50 per inch, and mounted on a frame, the outside dimensions of which were five by six inches. The free area of the grid (inside dimensions of the frame) was four by five inches and it was spaced about 1/16 inch from the electrophotographic plate surface. The grid was placed in the plane of the top, or open side, of the box. The box, the grid, and the back of the electrophotographic plate were all maintained at zero potential for the tests made to compare the characteristics of the various types of baffles and brushes.

The developer consisted of a mixture of Alj powder and uncoated glass beads in the ratio of 1 to 12 by weight, respectively.

For the agitators (a), (b), (c), (d), and (e) in Figure 160, the length of stroke used was 1-1/4 inches and the frequency of reciprocation was about 120 strokes per minute. The length of stroke was limited to 1-1/4 inches, because four or five baffle plates were mounted on the rod. These above five baffles were reciprocated in a direction parallel to the long dimension of the box.

The brush agitator (f), on the other hand, consisted of a single brush, mounted to reciprocate across the width, or five-inch dimension, of the box. Its stroke length was approximately four inches. An 18-mesh



CUTAWAY VIEW OF AGITATOR-TYPE, POWDER-CLOUD BOX

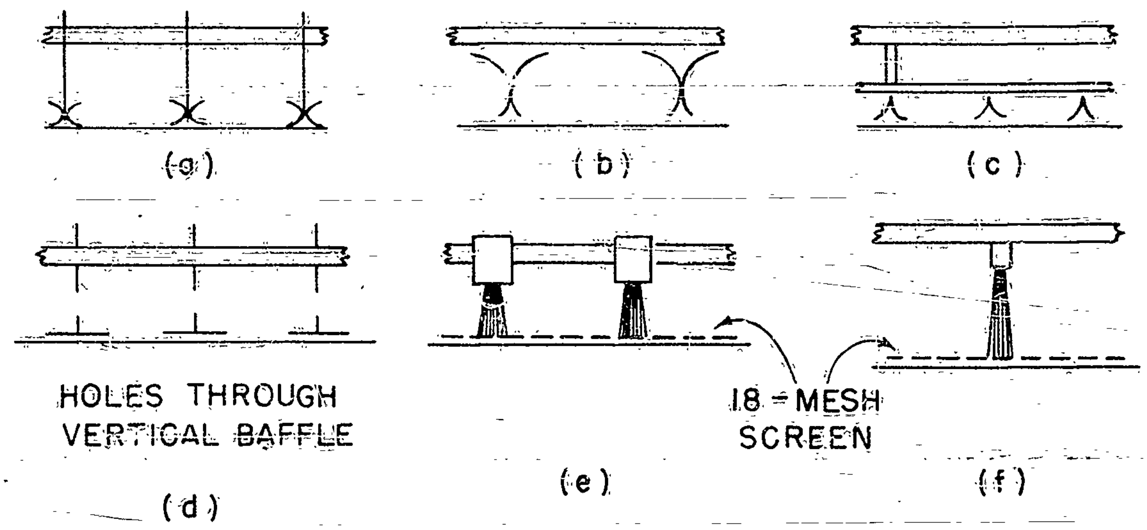


FIGURE 160. AGITATOR-TYPE, POWDER-CLOUD BOX AND VARIOUS DESIGNS OF RECIPROCATING BAFFLES AND BRUSHES

0-14741

screen was fastened to the bottom of the box to provide an irregular surface for the bristles to brush against, thereby producing a more dense cloud. The bristles were of horse hair, one inch long.

Results of Tests on Agitator Designs

The baffles (a) and (b) (see Figure 160) did not produce a sufficiently dense cloud to develop an electrophotographic image. The objection to design (c) was that it either threw both powder and glass beads against the plate, or did not produce a powder cloud at all.

Design (d) was the most successful of the baffles, in that it produced the most dense and uniform cloud of any of the baffle designs; however, it suffered from the same fault as the others in that it was not capable of consistently producing a sufficiently uniform cloud. This was particularly troublesome if, due to tilting or shaking of the box, the developer collected to one side of the box.

The brush agitators were more successful than the baffles in producing uniform cloud consistently. The brush shown in (f) of Figure 160 was the better of the two designs in that the cloud was more uniform in density across the plate surface. The density of the cloud was greater at the ends of the brush stroke, however. It was to reduce the area and magnitude of this "end effect" that this brush was reciprocated across the width of the box rather than along its length. Stationary baffles, with their surfaces horizontal, and placed over the stroke-end positions of the brush, improved cloud uniformity somewhat. Increase in the depth of the box to 2.5 inches also improved cloud uniformity to some extent, but further increase in depth only decreased the uniformity.

The principal fault of this single-brush design, the best design found to date for producing a powder cloud in an enclosed box, is that the average cloud-particle size is not as small as the particle size in the developer powder used. This results in a tendency to produce agglomerates of powder which give rise to undesirable graininess in the developed images. A second fault is that this single-brush design produces cloud particles of both negative and positive polarities. Ways of coping with this problem are discussed in another section of this report entitled "Control of Polarity of Cloud-Particle Charge". However, if proper care is exercised in the developing operation, powder images can be formed which are acceptably dense, fine grained, and of good over-all appearance. These factors, concerning the care which must be taken, are discussed in detail in several other sections of this report.

Several other methods of producing a powder cloud, which were unsuccessful, include scraping or beating either cloth, carpeting or cotton batting, which has been saturated with developer powder. Although two of these, the scraping of a blade over powder-laden cloth or carpeting, were capable of producing dense clouds of powder when first used, they were unsatisfactory because they became depleted of powder so rapidly as to require frequent retoning. This need for frequent retoning meant that cloud density varied widely from print to print, a very undesirable characteristic.

Control of Polarity of Cloud-Particle Charge

It is necessary for effective potential cycling of the grid during development to have particles in the cloud of only one charge polarity. If, for a positively charged plate, some cloud particles with a positive charge are present, they will deposit on the highlight areas when the grid potential is raised in cycling. The presently used, brush-type, powder-cloud boxes produce a small, but not neglectable quantity of positive powder.

The polarity of the cloud of particles reaching the plate can be controlled by three basic methods.

The first method is to produce particles of only one polarity. This may involve the use of materials for the brush, box, and carrier which are high in the triboelectric series compared to the material of the particle itself. Contact of the particles with this material, as the cloud is produced, charges the cloud particles negatively. This has been experimentally accomplished by coating the bristles of the brush and the interior of the box with polyvinyl acetate. However, as the box is used, negatively charged powder collects on the interior of the box, shielding the coating and permitting positively charged powder to be produced again.

The second method of producing a cloud of particles charged to the same polarity is to charge the particles after the cloud has been produced. This can be accomplished to a great extent by passing the particles through a field sustaining a corona discharge. Experimentally, this method appeared to accomplish its purpose. However, its use in the development box was precluded, because the ionization produced reached the plate being developed and caused it to lose potential.

The third method of controlling the cloud polarity at the plate is to sort out the particles having the wrong charge. This can be done electrically by using a sorting grid between the cloud generator and the development grid. The use of such a sorting grid has been described in Quarterly Report No. 3, page 295. It was reported there that the sorting grid, which was made of 1/4-inch hardward cloth, increased the density and uniformity of the images but, in addition, appeared to cause agglomeration of the powder deposited on the plate. The use of a sorting grid was also reported on page 323 of Quarterly Report No. 4 in which a potential of 800 volts negative was applied to the grid with effective results.

In the present work, the grid consisted of an array of wires, 0.010 inch in diameter, spaced one-half inch apart, and in a plane seven-eighths inch from the development grid. Sorting was more complete for higher sorting grid potentials, the upper limit of potential being the point at which corona discharge started. A potential of 3000 volts negative was found to be very satisfactory. No trace of positively charged powder could be detected in the developed image until the development-grid potential was raised to 180 volts, positive. At this voltage, a very slight amount of powder deposited on the extreme high-light areas.

EXPERIMENTS ON CHARGING, EXPOSURE, AND DEVELOPMENT

H. E. Carlton, D. L. Fauser, R. B. Landrigan, D. F. Mosley, R. E. Tom, and O. A. Ullrich

Effect of Plate Potential on Graininess of Image

The study of the effect of initial plate potential on the graininess of the powder image produced on the plate has been continued. The previous work on this subject was described in Quarterly Progress Report No. 6, pages 486-488. There it was reported that much image graininess results from overcharging the selenium plate, causing breakdown in the selenium layer, which apparently damages the plate permanently. This damage, and the graininess due to it, can be avoided by sensitizing the plate under special conditions with a potential-control charging unit (Quarterly Progress Report No. 5, pages 415-417).

The plate can be damaged by overcharging in at least three operations carried out on electrophotographic plates: (1) testing of the plate, (2) sensitizing of the plate, and (3) electrostatically transferring the powder image from the plate.

Damage from sensitizing the plate was observed on some 18-micron-thick selenium plates when they were charged to potentials as low as 25 volts. By increasing the thickness of the selenium layer, the potential to which the plates can be charged before they develop this breakdown damage is also increased. A 50-micron-thick plate can be charged to about 300 volts (positive potential) before breakdown begins to occur. Thicker plates will sustain even higher voltages before breakdown, but are not usable in the process at present because of excessively high residual potentials which also result. Repeated charging of 50-micron plates to potentials near this 300-volt limit value often causes moderate breakdown to gradually develop. Although no study has been made with regard to safe limits of potential for repeated chargings, avoidance of graininess in prints due to selenium-layer breakdown, recommends the use of as low charging potentials as possible. An average 50-micron plate will not develop noticeable breakdown damage when charged to 275 volts or less in 20 or 30 chargings.

Operating Characteristics of the Haloid-Built, Potential-Control Charging Unit

In order to more effectively control the potential to which a plate will be charged, the potential-control-grid charging device is used. This device was first described for this project in Quarterly Report No. 5, page 414.

An improved model of the potential-control charging unit has been designed and made at The Haloid Company, and several of these units have been provided for experimental use at Battelle Memorial Institute.

The operating characteristics of this potential-control grid, corona charging unit built at The Haloid Company, have been studied to determine the effect of each of four variables on accepted [illegible] potential. These variables were: (1) potential on grid wires, (2) potential on corona wires, (3) spacing between plate and g[illegible] traverse rate of plate under charging unit. The curves in Figures 161, 162, and 163 show these relationships.

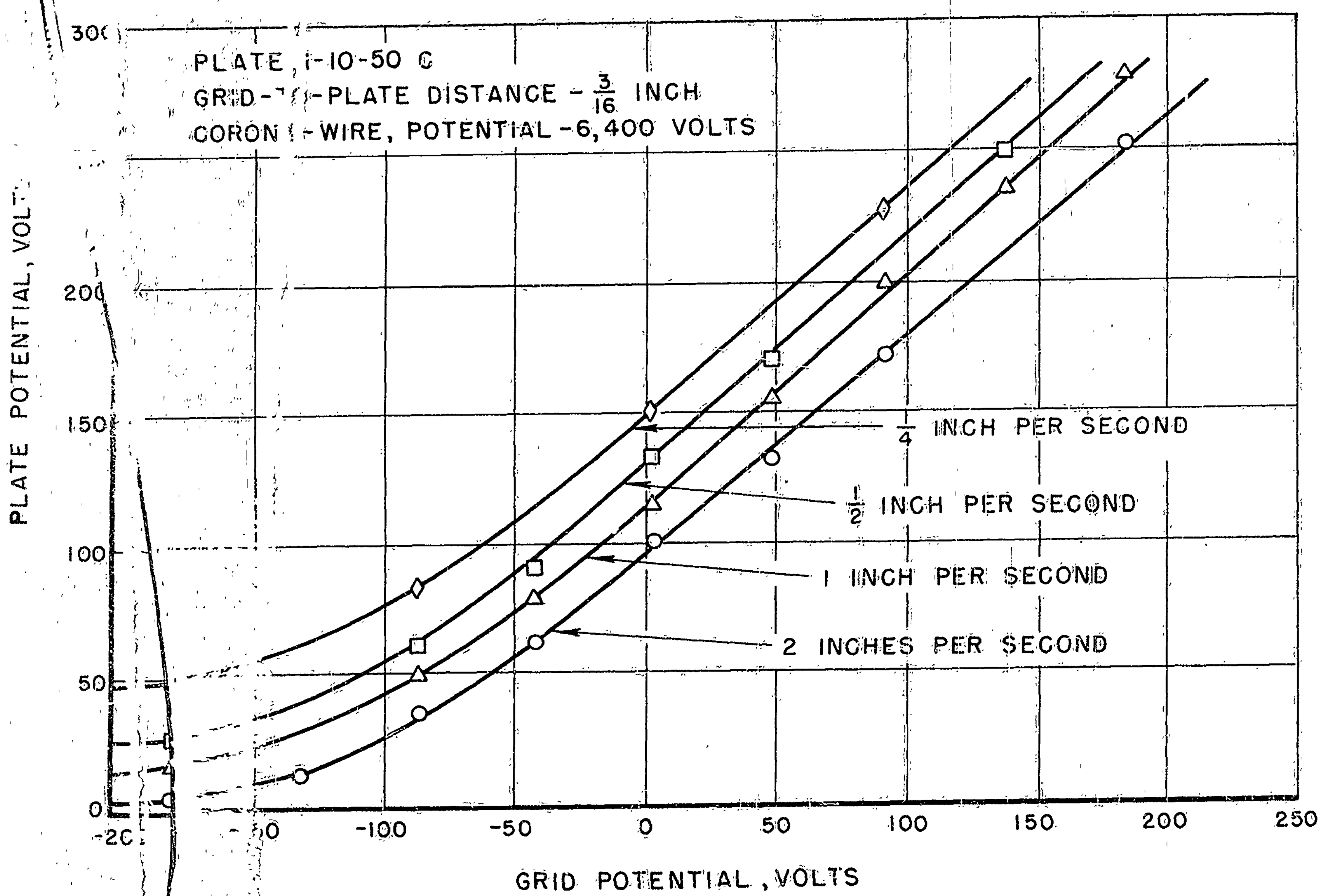


FIGURE 131. VARIATION OF PLATE POTENTIAL WITH VOLTAGE ON CHARGING-UNIT GRID FOR SEVERAL TRAVERSE RATES

0-14742

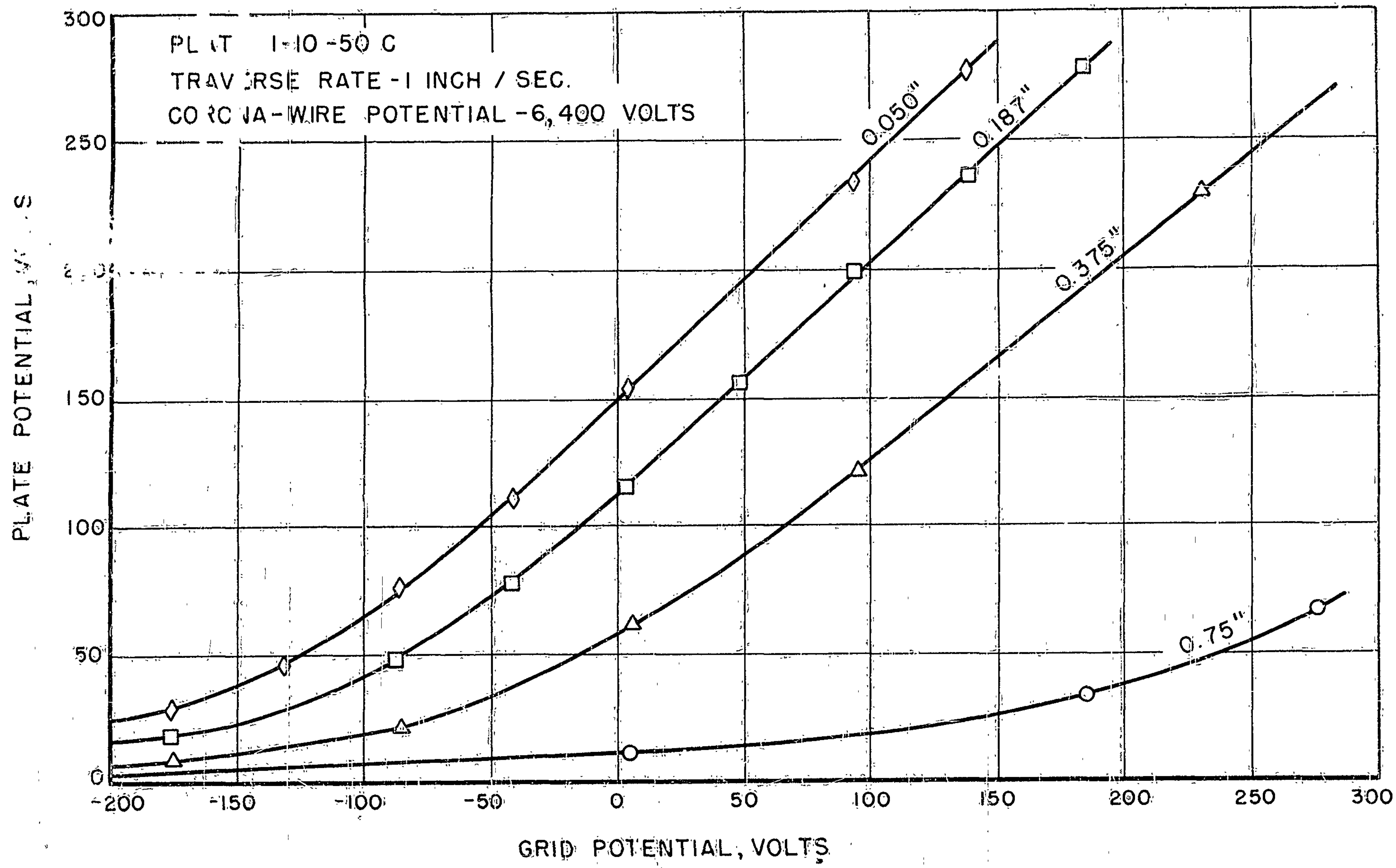


FIGURE 162. VARIATION OF PLATE POTENTIAL WITH VOLTAGE ON CHARGING-UNIT GRID FOR SEVERAL GRID-TO-PLATE SPACINGS

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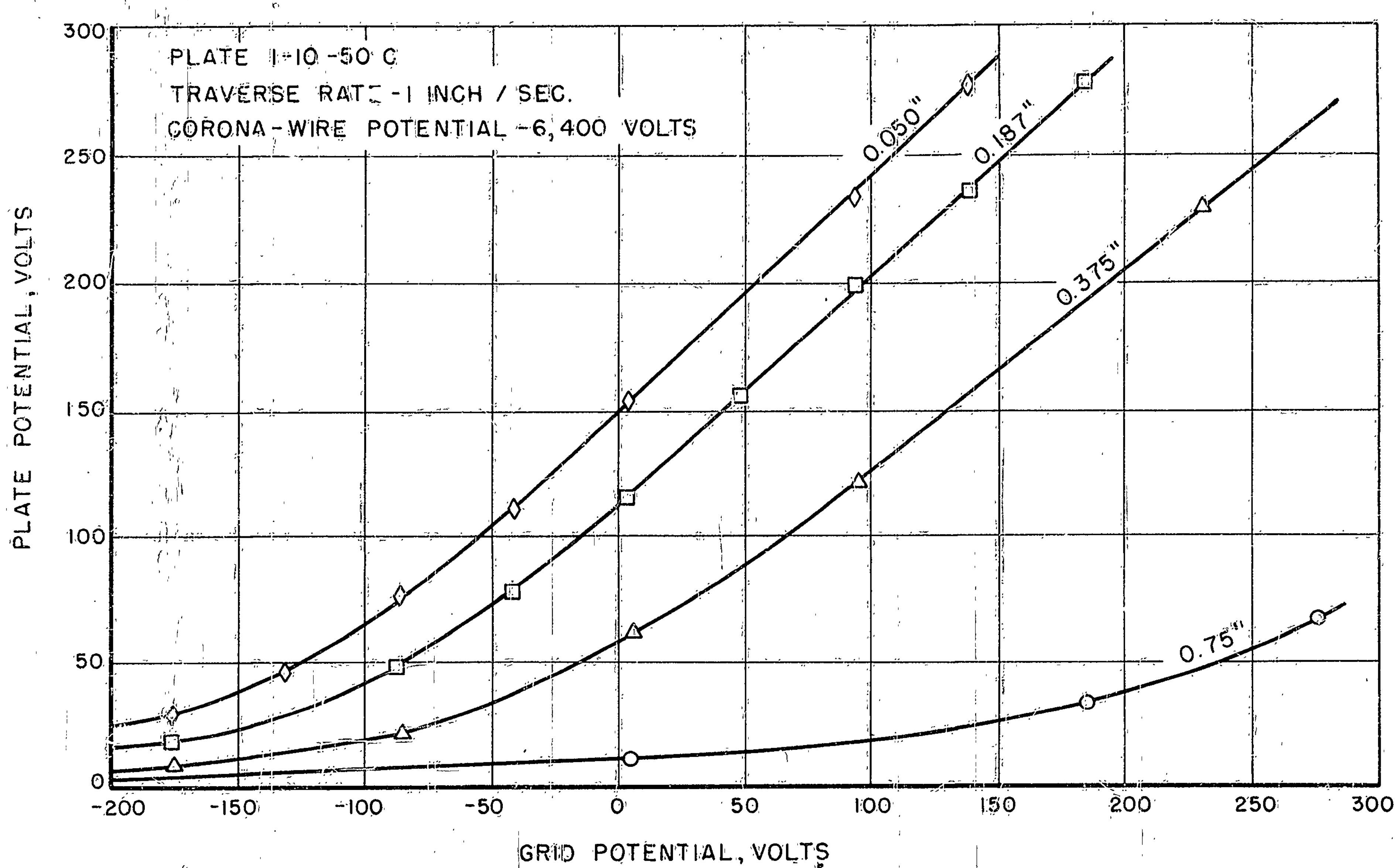

FIGURE 162. VARIATION OF PLATE POTENTIAL WITH VOLTAGE ON CHARGING-UNIT GRID FOR SEVERAL GRID-TO-PLATE SPACINGS

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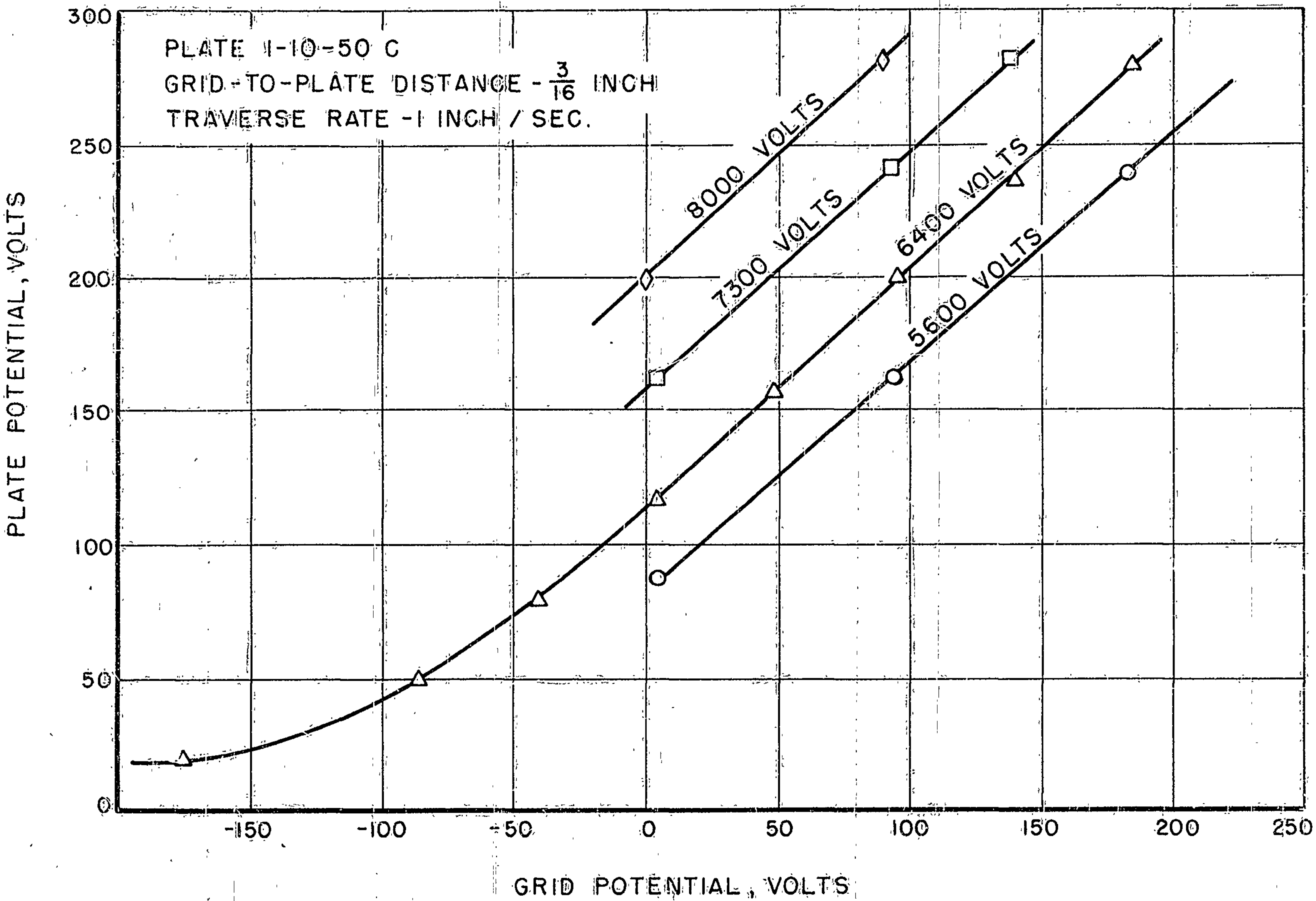

FIGURE 163. VARIATION OF PLATE POTENTIAL WITH VOLTAGE ON CHARGING-UNIT GRID FOR SEVERAL CORONA-WIRE VOLTAGES.

0-14744

Data from these curves can be used to determine the limits of variation of each parameter measured for any given plate-potential variation. In the following table these values are listed, along with the conditions which have been chosen as standard.

TABLE 43. PROPOSED STANDARDIZED CONDITIONS FOR POTENTIAL-CONTROL CHARGING UNIT

	Standardized Values	Limits of Variation
Plate potential	275 volts (max.)	± 5 volts
Corona potential	6400 volts	± 90 volts
Grid-to-plate spacing	0.187 inch	± 0.015 inch
Traverse rate	1 inch per second	± 0.18 inch per second
Grid potential	180 volts	± 5.5 volts

The effect of corona-wire potential on corona current, grid current, and current to the plate being charged, was also measured. These data are plotted in Figure 164.

Two other constants of the charging unit were determined. These involved the potential of the plate as a function of its position with respect to the charging unit. The first measured the potential of the plate as it progressed under the grid wires. The second measured the potential of the plate under and beyond the end of the charging unit, in a direction parallel to the grid wires. Figures 165a and 165b show the results of these tests.

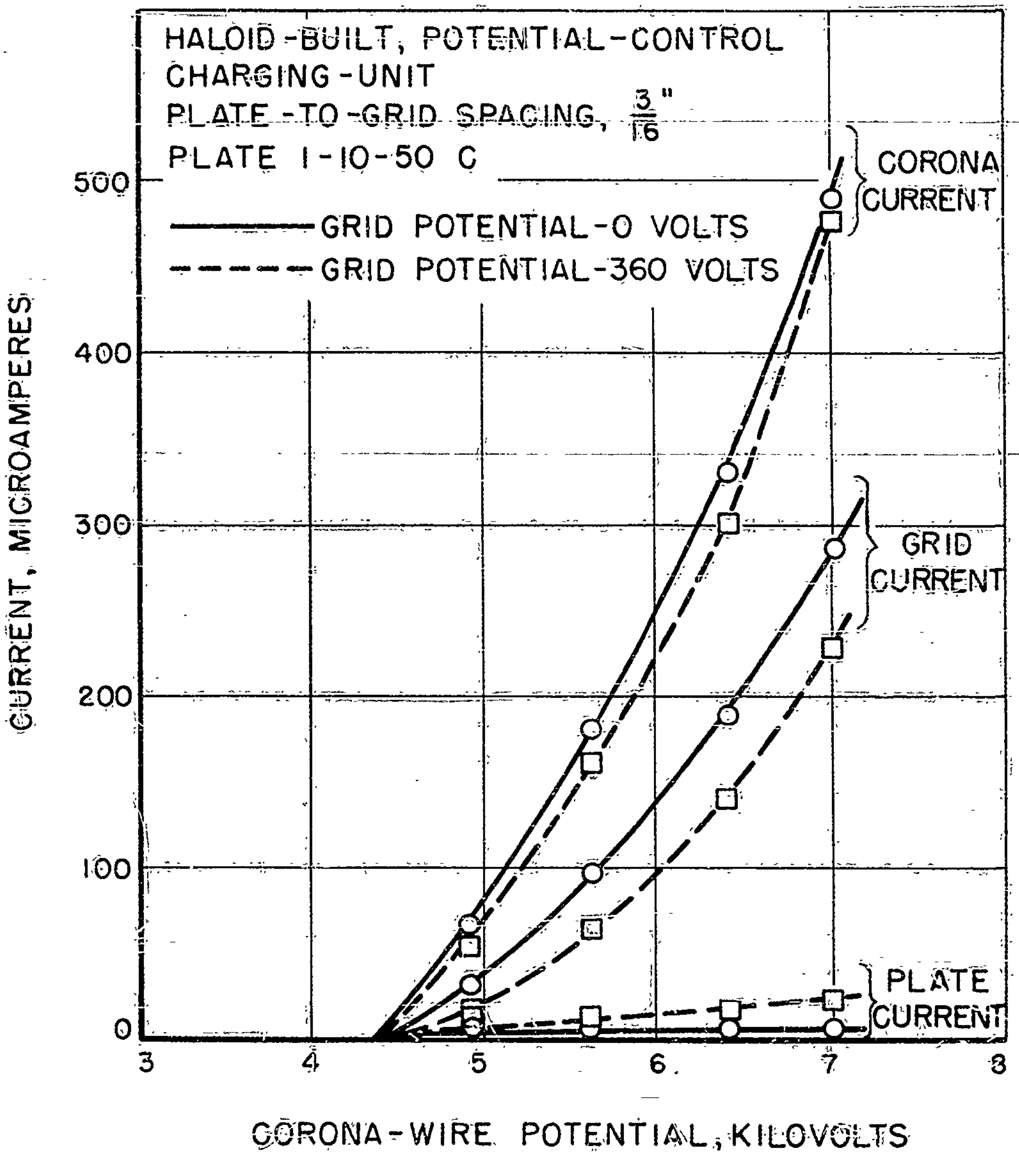

FIGURE 164. VARIATION IN CURRENT WITH CORONA-WIRE POTENTIAL

0-14745

+ 90 VOLTS ON GRID, + 6,400
VOLTS ON CORONA WIRES
$\frac{3}{16}$ INCH GRID-TO-PLATE SPACING

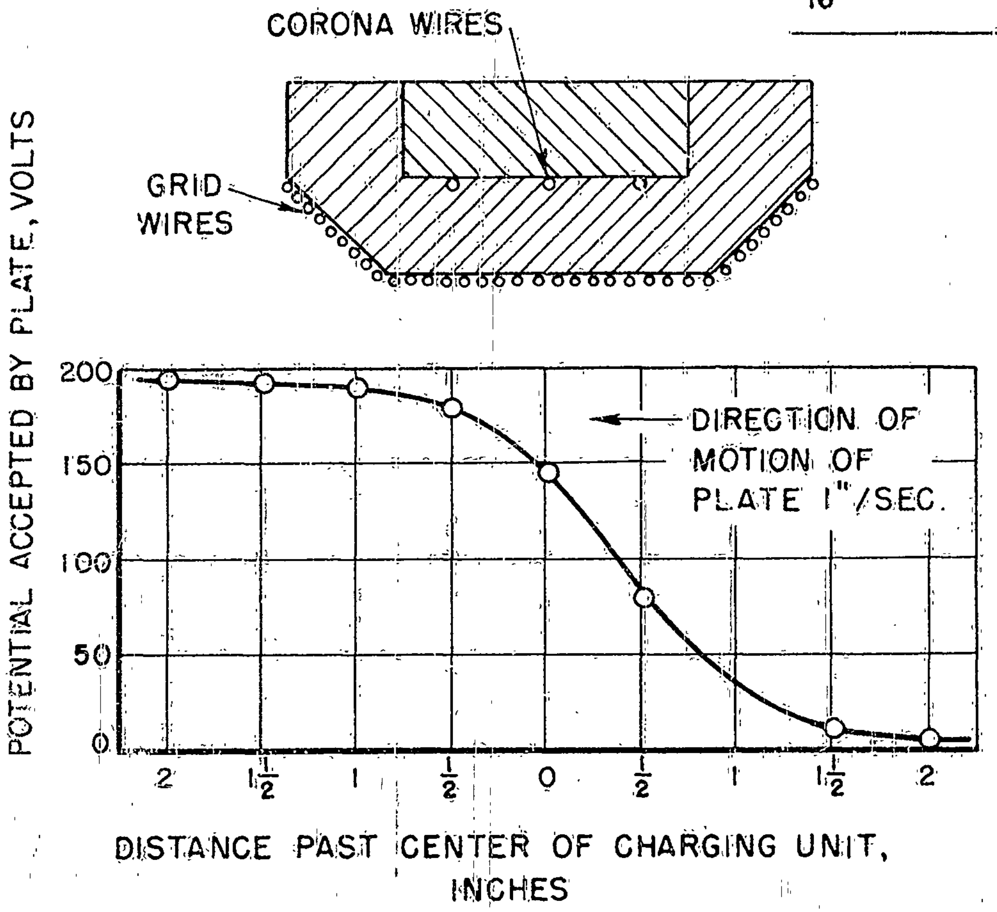

FIGURE 165 a. POTENTIAL ACCEPTED VS. POSITION, FOR PLATE PASSED PART WAY UNDER CHARGING UNIT

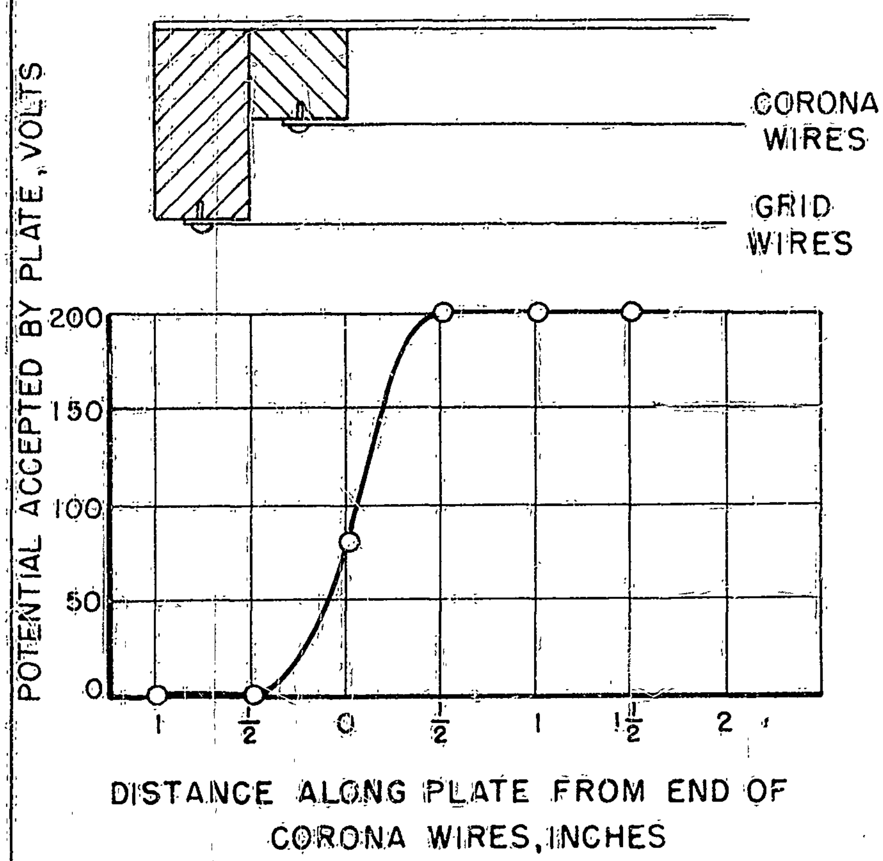

FIGURE 165 b. POTENTIAL ACCEPTED VS. POSITION OF PLATE WITH RESPECT TO END OF CHARGING UNIT

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Although the potential-control-grid charging unit is very effective in controlling the potential to which any given plate may be charged, it does not in itself completely govern the charging operation. Accepted plate potential is still, to some extent, affected by selenium-film thickness (even when charged well below its maximum value) and duration of the charging period.

The first independent factor mentioned as affecting plate potential was the thickness of the selenium. A thicker plate, or thicker areas of one plate, will accept a higher potential than a thinner plate. This difference is, in some cases, roughly proportional to the thickness.

With regard to duration of charging, Figure 166 presents data taken on the vibrating-probe electrometer in which a potential-control grid was used for charging. It shows clearly that, for any given geometry and potential on the charging unit, a certain minimum time interval, generally several seconds or more, is required for the plate to reach its final potential. This is also shown in Figure 161, in which final potential proved to depend greatly on the traverse rate of the plate.

Effect of Initial Plate Potential on Image Density

The effect of maximum plate potential on image density was investigated to aid in establishing voltage tolerances for the charging operation. It was found that, for the same exposure, images made from a plate charged to 150 volts were only slightly less dense than images made

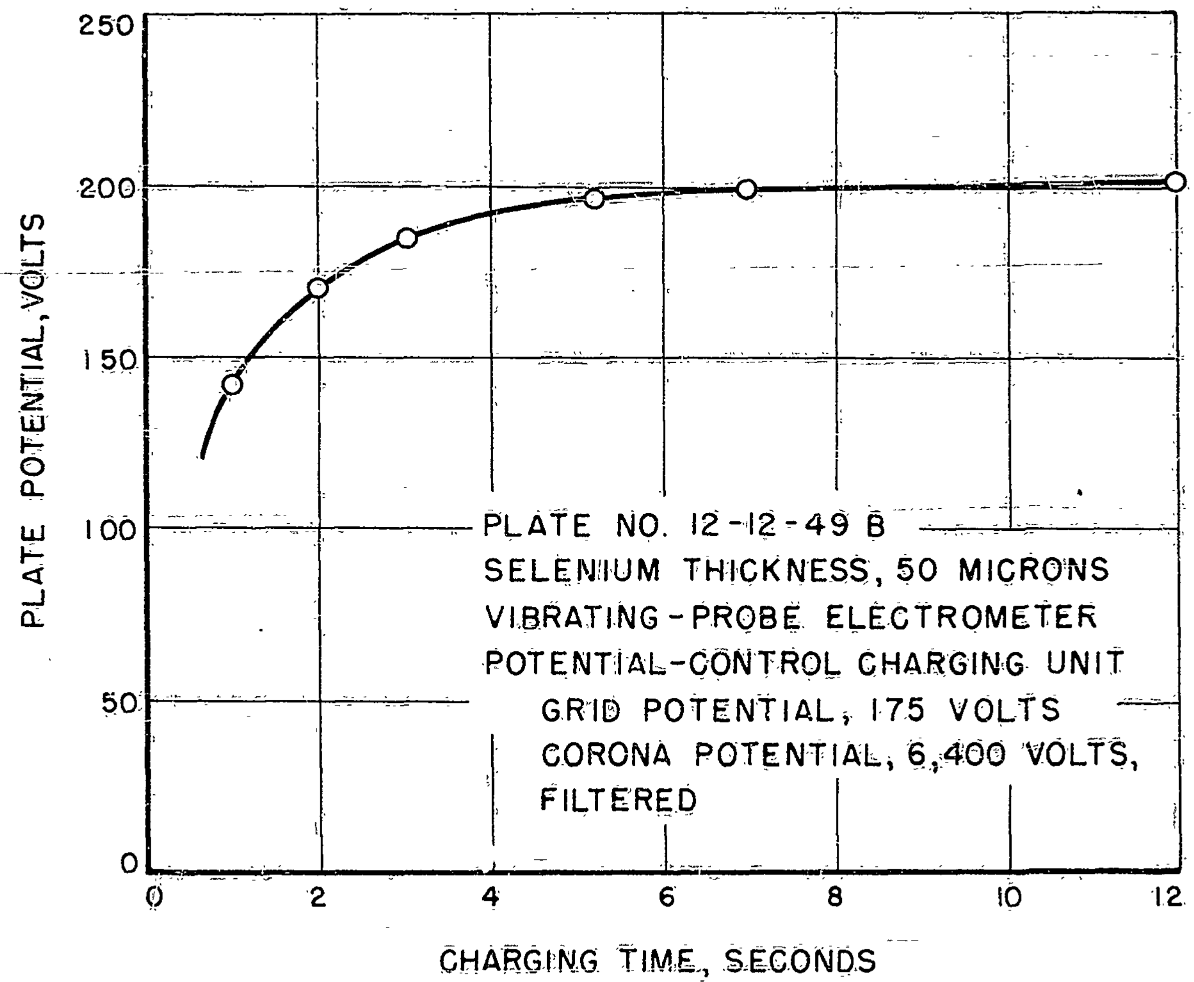


FIGURE 166. ACCEPTED PLATE POTENTIAL VS. DURATION OF CHARGING PERIOD

0-14747

from the same plate when charged to 280 volts. Therefore, a large variation in initial plate potential can be tolerated from one charging to another, and still obtain prints of acceptable image density. This conclusion is based on work with three separate plates.

The potential variation permissible across the surface of a plate is very much smaller than the value cited above, however. To attain acceptable uniformity of density within any given small area of a print, the potential variation in this area must not be greater than plus or minus approximately two per cent.

Effect on Image Density of Long Time Intervals Between Charging and Development

A study was made to determine permissible time intervals between plate sensitization and exposure and between exposure and development. It was found that, using the plates prepared under the conditions described on page 606 in the Appendix of this report, time intervals up to 70 minutes can be tolerated with practically no loss in maximum print density and no noticeable effect on tonal rendition. Such a time interval can occur either before or after exposure.

This work was carried out with three plates, No. 1-13-50 D, No. 1-16-50 I, and No. 1-16-50 H. These plates were charged to 200 volts potential, exposed in a camera to a silver halide continuous-tone print, and developed in a brush-agitator powder-cloud box. A grounded, 50 wire per-inch, development grid was used. Minimum time intervals possible, due to necessary handling time, were 1 minute between charging and exposure and 1 minute between exposure and development.

The whole process generally proved to be repeatable; that is, when the same time intervals were used, the image densities generally appeared the same to the eye. However, at times, differences in print density did appear in images made under supposedly similar conditions. These differences were often greater than differences which appeared between images made using short time intervals and images made using long time intervals. Thus, it was shown that the effect of varying time intervals up to 70 minutes is generally no greater than the effect of variations in the developing apparatus itself. These results are in excellent agreement with results to be expected from the slow, dark-decay rates of the plates, and also from the wide limits of initial potential which will produce satisfactory prints.

The effect of a 20-hour period between charging and exposure was also investigated. In this case, the developed image showed a very decided decrease in overall density. The picture was complete, however, all details showing nearly as well as in the prints developed after relatively short time intervals.

The effect of such an extended time interval between exposure and development has not yet been examined. Here, it would be expected that loss of detail and blurring of the image might result from both dark conductivity and surface conductivity on the plate. A careful cleaning procedure can eliminate difficulty with surface conductivity, at least at moderate humidities.

An adequate cleaning procedure consists of wiping the plate surface with a cotton swab saturated with absolute alcohol, blotting the surface dry, and exposing the plate to a warm-air current for five or ten minutes.

As reported above, time intervals up to 70 minutes between sensitization and development have appeared to cause no significant drop in image density in limited laboratory experiments. To allow for unforeseen variations which may appear in the field, a time interval of 20 minutes has been recommended for camera operation.

The Development-Control Grid

A cursory study of the use of the development-control grid was undertaken to obtain data required for the design of the electrophotographic camera.

Wire spacing in the grid, and the spacing between the grid and the plate were evaluated as to their effect on graininess, fidelity of tonal reproduction, amount of halo and general appearance of the image. The developer used was Al-5 powder with uncoated glass beads (1 to 12 ratio, by weight). Both the oscillating, compartmented tray and the brush-type, powder-cloud boxes were used. The plate was contact exposed using the setup shown in Figure 169, presented in another section of this report. The grid consisted of 0.003-inch-diameter wires mounted on a 1/2-inch angle-iron frame with outside dimensions 5 by 6 inches.

Wire spacings in the grids used for this work were 30, 60, and 100 wires per inch. The spacing between the grid wires and the plate to be developed was varied from 0.020 inch to 0.120 inch.

The results were as follows:

1. Lines appear in the print due to grid-wire shadowing when the grid is placed too close to the plate during development. The spacing at which the lines just begin to appear, defined here as critical spacing, is dependent upon the potential difference between the plate and the grid; the greater the potential difference, the greater is the critical spacing. Using the shaker-tray, powder-cloud box, the following data were obtained:

Grid With 30 Wires Per Inch		Grid With 60 Wires Per Inch	
Critical Spacing, Inch	Potential Between Plate and Grid, Volts	Critical Spacing, Inch	Potential Between Plate and Grid, Volts
0.040	22	-	-
0.054	90	0.054	22
0.089	180	0.089	160

These data are presented only to show about what values can be expected. There are other factors which influence this interdependence of voltage and critical spacing, among which may be the type of powder used and the charge on the powder. For example, using the brush-type powder box, a potential difference of about 200 volts can be used with a plate-to-grid spacing of 0.045 inch. This is considerably more potential difference than was permissible when the shaker box was used.

2. No difference in image quality was observed between the grids with 30, 60, and 100 wires per inch when each was used at slightly greater than its critical spacing.

3. Development is faster, the closer the grids are placed to the plate.

4. The closer the grid is to the plate, the less the halo effect becomes.

5. Development rate decreases as the grid-wire spacings become closer.

6. For best image quality and reproducibility, the grid wires must be cleaned of powder particles before each use.

Effect of Cycling the Grid Voltage During Development

One promising method of improving the tonal rendition in electrophotographic prints is by properly adjusting, or cycling, the voltage on the development grid during the development of an image. The basis for development-grid cycling and the procedure for accomplishing it were set forth in Quarterly Progress Report No. 6, pages 482 through 485. Results obtained subsequently show that it is possible to improve the tone quality of continuous-tone images by development-grid cycling, using the brush-type powder-cloud box. Effective control, which results in a faithful reproduction of the subject, is very difficult to achieve and requires extensive knowledge of exposure and development conditions. (In the work reported here, grid cycling has consisted of using a series of voltages only once during the development of an image, rather than repeating the series once or more during the development.)

A gray-scale transparency was used to determine the relation between image density and subject density for different development-grid potentials. The solid lines in Figure 167 plot image density versus subject density for positive grid potentials of 0, 45, 90, and 135 volts.

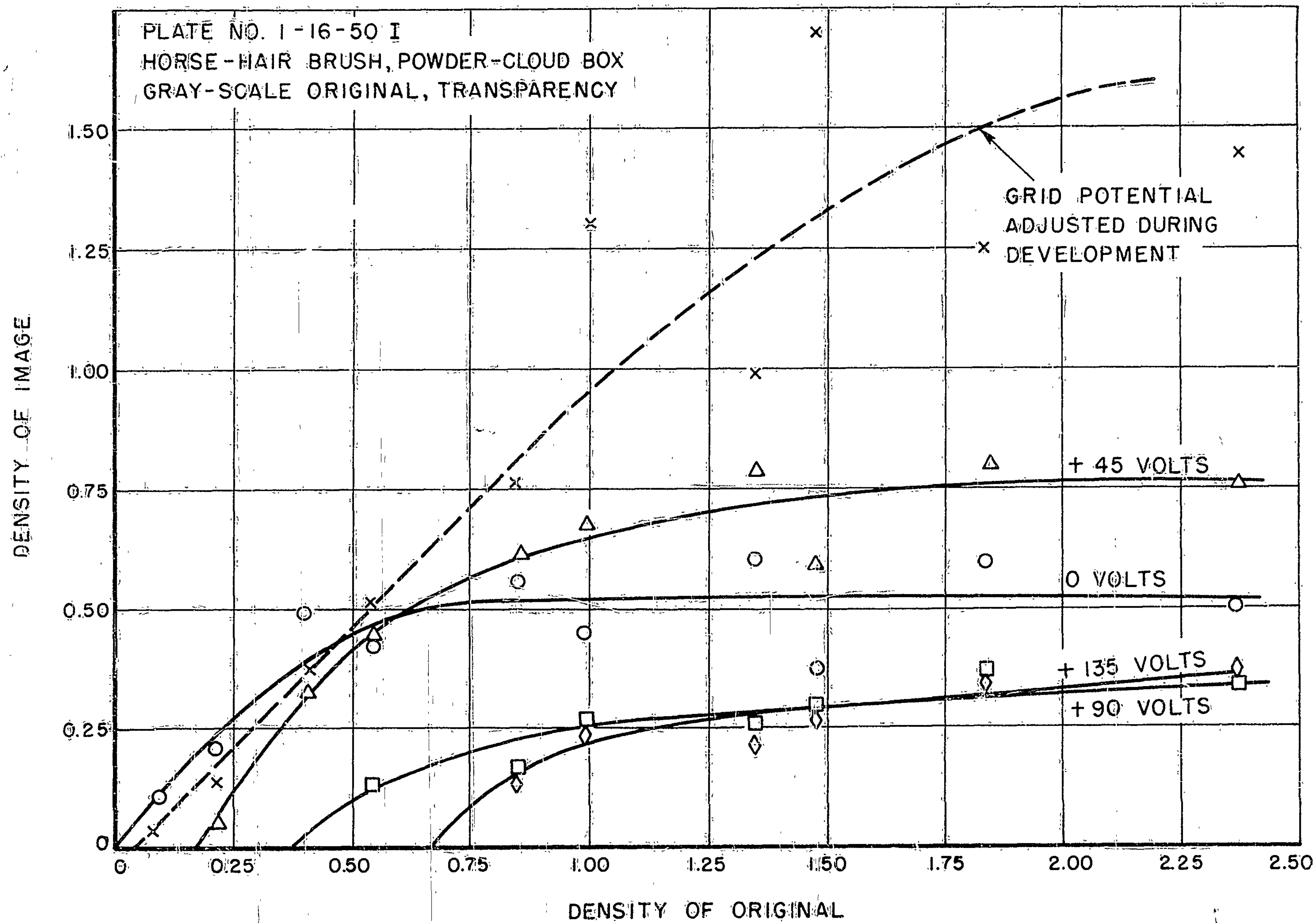


FIGURE 167. DENSITY OF PRINT VS. DENSITY OF GRAY-SCALE ORIGINAL FOR FOUR DIFFERENT DEVELOPMENT-GRID VOLTAGES

0-14748

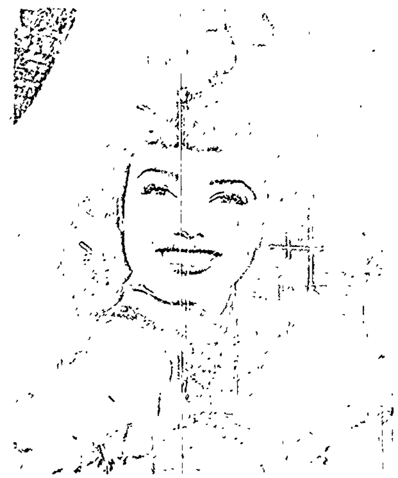
Sixty complete strokes of the brush agitator were used to produce the densities in the image. A reflection densitometer was used to measure the image density. By developing a gray scale in which these different voltages were applied successively, a gray scale having densities corresponding to the broken line in Figure 167 was obtained. For this gray scale, the development consisted of 50 strokes of the brush at zero volts on the grid, 20 strokes at +45 volts, 50 strokes at +90 volts, and 150 strokes at 135 volts. The choice of number of strokes at the given voltages was somewhat arbitrary, but it was based on a study of the solid-line curves in the graph. This study showed that density in the image became deficient at about 0.4 and that the two highest voltages started depositing powder at and above this density.

The wide spread in points for the broken line is due to non-uniform particle distribution in the cloud. The broken line does, however, represent a definite improvement in linearity between image density and subject density.

A continuous-tone, silver halide print was then used as the subject to study the effect of grid-potential adjustment during development. A series of electrophotographic prints were made at three different grid voltages, -45, +45, and +112 volts, respectively. These pictures are shown in Figure 168. Sixty strokes of the brush agitator were used. The effect of the different voltages can readily be seen, particularly in the difference in the quantity of powder deposited in the highlight areas. The picture made at 112 volts is very badly "washed out". The picture at -45 volts is of very low contrast, but does have

-45 VOLTS ON GRID,
60 STROKES OF BRUSH

+45 VOLTS ON GRID,
60 STROKES OF BRUSH



+112 VOLTS ON GRID,
60 STROKES OF BRUSH

CYCLED PICTURE

-45 VOLTS ON GRID FOR 10 STROKES OF BRUSH
+45 VOLTS ON GRID FOR 10 STROKES OF BRUSH
+112 VOLTS ON GRID FOR 200 STROKES OF BRUSH

FIGURE 168. PICTURES SHOWING THE EFFECT OF DEVELOPING WITH DIFFERENT VOLTAGES ON THE DEVELOPMENT GRID AND THE EFFECT OF CYCLING

68577

some powder in all but the extreme highlight areas, such as the teeth. The picture at +45 volts has the best density balance but leaves the face too contrasty. (Similar effects of the development-grid potential were shown on page 294 of Quarterly Report No. 3. They were made under more adverse conditions of plate quality and development technique.) A composite of these three using 10 strokes at -45 volts, 10 strokes at +45 volts and 200 strokes at +112 volts, is also shown in Figure 168. This is an example of the type of result that grid-potential adjustment can accomplish, but the exact voltages and number of strokes to use at each voltage are very dependent upon the initial charging potential and the exposure.

These continuous-tone images were made using camera exposure of a silver-halide-print subject illuminated by two Kenry flash lamps. The powder-cloud box had a development-control grid made with wires 0.003-inch diameter spaced 0.02 inch apart. The grid was placed approximately one-sixteenth inch from the plate. The developer consisted of uncoated glass beads and Al-5 powder, in the ratio of twelve to one by weight, respectively. The plate was charged to 200 volts, positive potential.

Reproducibility of Image Density Using Brush-Box Development

A preliminary study was made to determine the variation which can be expected in density of prints made under fixed conditions with the brush-type, powder-cloud box. Under the conditions described below, a variation in density of 0.1 at an average density of 0.8 can be expected. About 10 to 12 prints could be made with a single charge of developer before print density began to decrease as the result of the powder being used up.

The tests were made with three different plates, No. 1-12-50C, No. 1-12-50D, and No. 1-12-50F, which were used in rotation. They were charged to approximately 260 volts using a potential-control charging unit, and exposed to a gray scale using tungsten illumination. The exposure was controlled by means of the iris diaphragm stop and the shutter of a 12-inch, f-4.5 lens. The arrangement of these parts is shown in Figure 169.

The developer box was of the standardized 5- by 6- by 2-1/2-inch size, and had a horse-hair-brush agitator. (This unit is described more completely on page 530 of this report.) The test was carried out using a single 65-gram charge of developer in the box. The developer consisted of Al-5 powder and uncoated glass beads in the ratio of 1 to 12, by weight, respectively. Forty complete cycles of the brush at a rate of about two cycles per second were used for the development of each image.

A total of 24 exposures and prints were made. After each exposure to the gray scale, the potential of each step area on the plate was measured. The plate was then developed, the powder transferred by the adhesive method, and the optical densities of each step were measured with a reflection densitometer. The results of these measurements on one of the intermediate density steps of the gray-scale original are plotted in Figure 170. This figure compares the plate-potential variation after

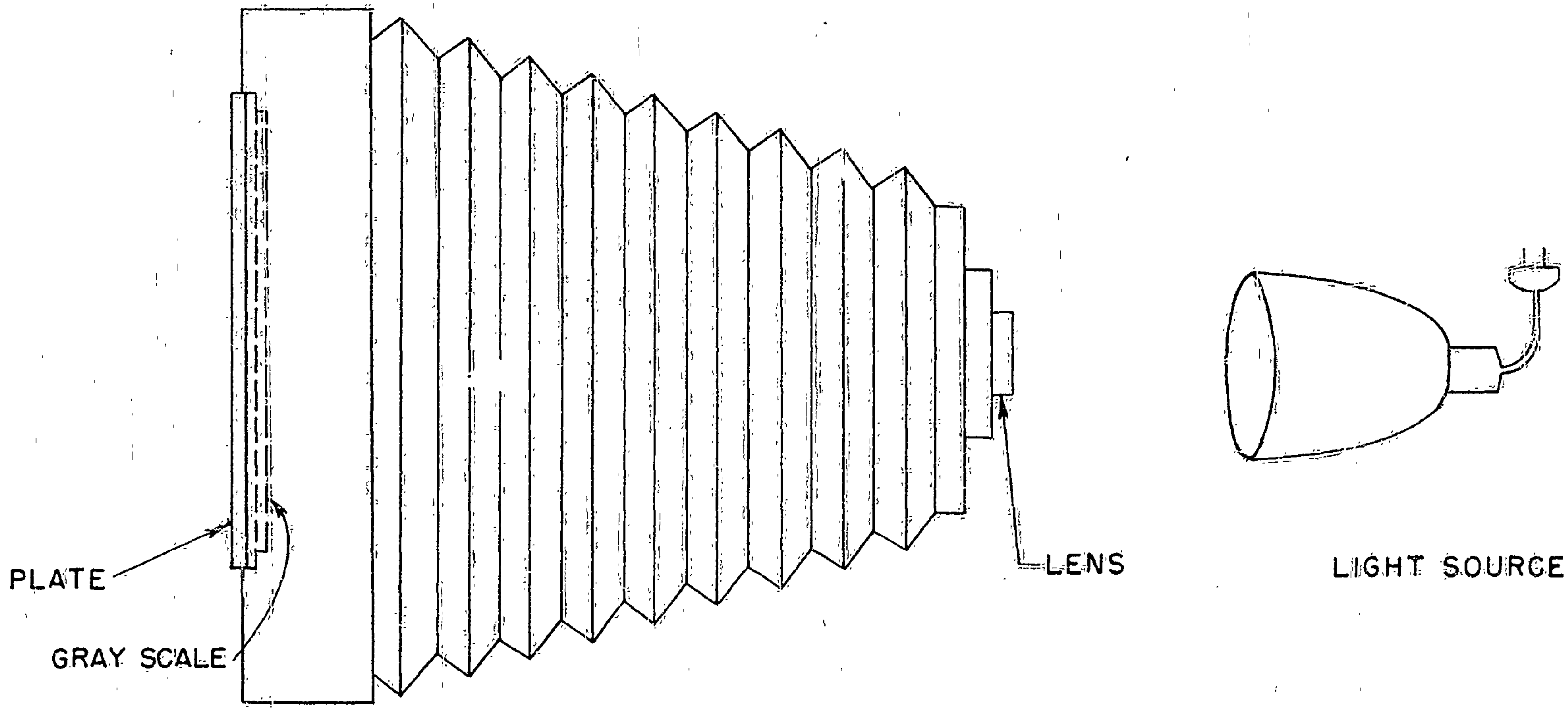


FIGURE 169. ARRANGEMENT OF CAMERA, LIGHT SOURCE, GRAY SCALE, AND PLATE FOR REPRODUCIBILITY TESTS.

0-14749

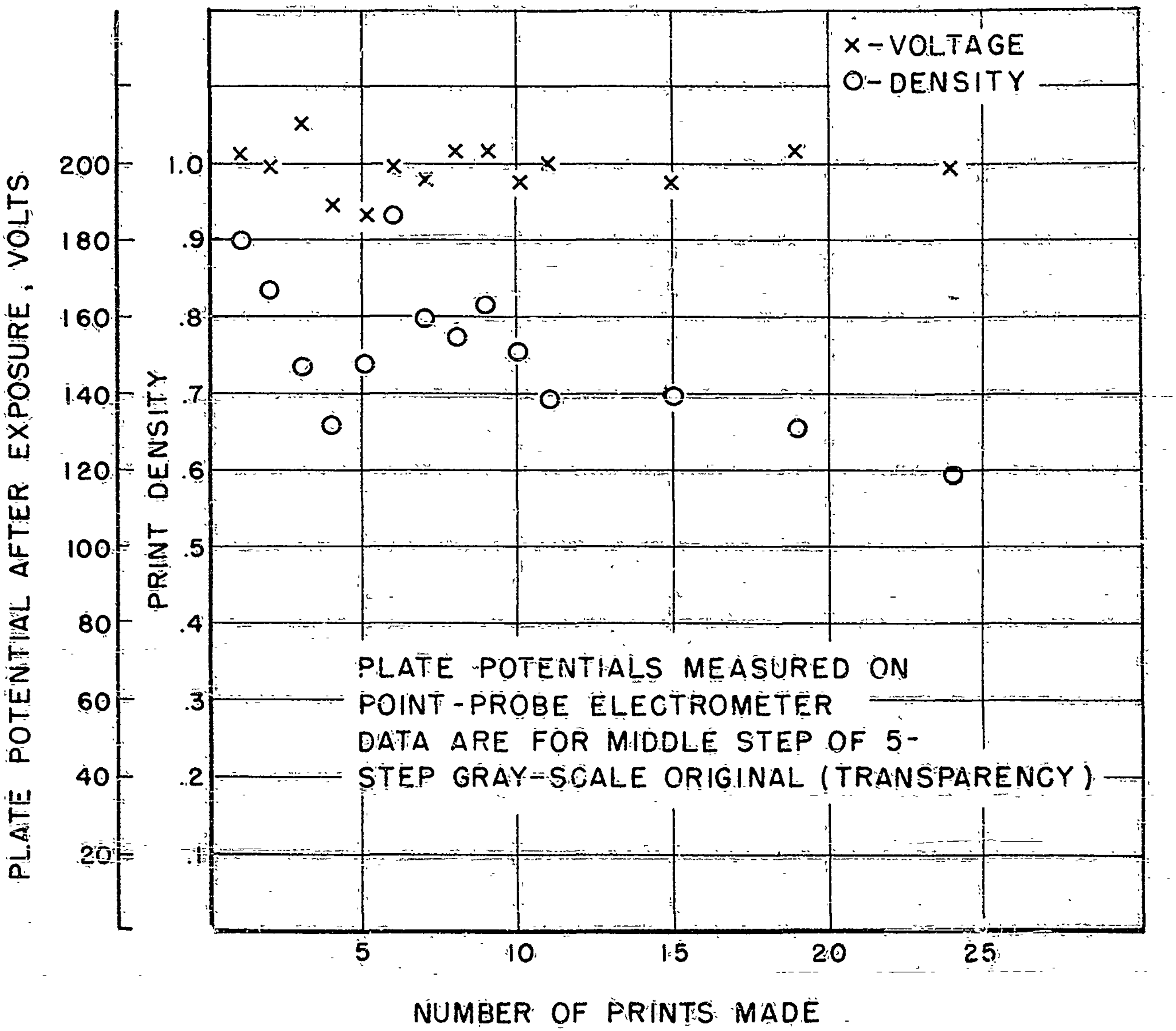


FIGURE 170. VARIATION IN PLATE POTENTIAL AND IMAGE DENSITY FOR SUCCESSIVE EXPOSURES TO GRAY-SCALE ORIGINAL, WITH ONE CHARGE OF DEVELOPER POWDER ONLY

0-14750

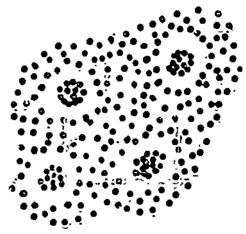
like polarity. The ultimate effect of such a behavior is that the larger particles, and particularly those which deposit first, will have powder-free areas or halos around them. In general, the larger the agglomerate, the larger the diameter of the halo. A sketch of this situation is shown in Figure 171(a).

It follows directly that the magnitude of the charge on both the single and agglomerated particles should also be a factor which governs the diameter of the halos formed. This has been found to be the case.

If the particles are of essentially the same size, the halo effect is still present, of course. It does not appear directly as a halo, however, but rather as it determines the average minimum spacing between the particles. In this case, particles with higher charge will distribute themselves on the plate surface with much greater spacings between them than particles of smaller size. This effect is sketched in Figure 171(b). Measurements of powder density, using the reflection densitometer, show that the higher the charge on the particles which deposit, the lower the density will be, all other conditions being constant.

Particle-Size Distribution in Powder Clouds

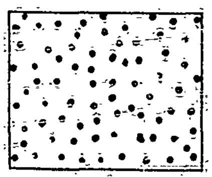
In Quarterly Progress Report No. 6, pages 494-495, one of the recommendations was to determine the magnitude of the charge on the individual particles and the total charge that would occur in a powder cloud. Information of this type would be very useful in evaluating powder-cloud deposits.



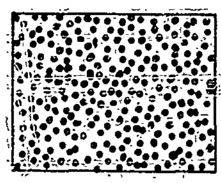
POWDER DEPOSIT WITH
AGGLOMERATES PRESENT

POWER DEPOSIT WITH NO
AGGLOMERATES PRESENT
(NOTE: SINGLE LARGE PARTI-
ICLES HAVE SOME HALO)

(a)



POWDER DEPOSIT WITH
HIGHLY CHARGED POWDERS



POWDER DEPOSIT WITH
LOW-CHARGED POWDERS

(b)

SCALE : $\frac{1}{4}$ INCH = APPROX. 30 μ

FIGURE 171. DIFFERENCES IN POWDER DEPOSITS DUE TO (a) AGGLOMERATION AND (b) CHARGE ON THE POWDER

In order to determine the magnitude of the charge on a particle, an electrostatic particle counter was built which consisted of a pick-up, pre-amplifier, amplifier, oscilloscope, scalar, and register.* By calibrating the oscilloscope, the charge of the particles can be determined, and by use of the scalar and register, the number of particles striking the pick-up can be determined. In the counting system, a discriminator will also be used which will permit the counting of only those particles which give a pulse voltage greater than a certain minimum value. By using selective discrimination at different voltages, while studying the same cloud, the number of particles falling into a certain charge range may be determined.

The construction of the ap aratus has been completed except for the addition of the discriminator. Preliminary tests show that the apparatus will work, since not only have particles been counted, but the magnitudes of charges have been estimated.

It is ancisipated that the following information may be obtained on powder clouds:

(a) Variations in cloud concentration and particle-size distribution.

(b) Clouds ranging in concentration from a few particles per liter to many million particles per liter can be studied and the effect of concentration on cloud behavior determined.

(c) The effect of mechanical and electrical disturbances on particle behavior.

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* A. C. Guyton - Journal of Ind. Hyg. & Tox., Vol. 28, 133 (1946).
F. T. Gucker & C. T. O'Konski - Chemical Reviews, Vol. 44 (1949).

(d) Decay of clouds (loss of cloud charge with time).

(e) Distribution of particles by charge and size can be compared.

(f) Difference in behavior between nonconducting and conducting particles, i.e., the manner in which charge varies with size in the case of each type of particle.

(g) Effect of velocity on particle charge.

ALTERNATIVE CONTINUOUS-TONE DEVELOPMENT METHODS

P. G. Andrus, D. L. Fauser, R. B. Landrigan,
and R. E. Tom

Powder-Spray Method of Development

A different method for producing a powder cloud, which consists of spraying dry powder from an air gun, has been used to develop images of exceptionally fine grain and pleasing tonal rendition. Pictures made by this powder-spray method approach in quality those made by the liquid-spray method, and show much finer grain than pictures made with the present brush-box development method.

The process has been most successful using a paint spray gun*, operated with air pressures from one to ten pounds per square inch. Developing powders which are most adaptable to this type of cloud generation have very fine particle size and good dry-flow properties. Charging of the cloud particles has been accomplished by passing them through a corona discharge just as they leave the spray gun. A diagram

* Paint Spray Gun, Type MBC, manufactured by The DeVilbiss Company, Toledo, Ohio.

of the experimental setup used is shown in Figure 172. Two prints which are representative of the image quality capable of the process are shown in Figure 173. These prints were made with the spray gun in the setup shown in Figure 172, using ball-milled charcoal as the developer powder.

The success of this method in producing prints of such fine grain quality is attributed to the fact that the developer powder is passed through a high-velocity air jet, which breaks up the powder mass, and produces a cloud consisting almost wholly of individual particles. To assure a positive and continuous feeding of the developer to the spray gun, without resorting to special feeding devices, it is necessary that the powders have good dry-flow properties.

The following powders have been used with the spray gun and found to feed well: Dry Flow*, pulverized charcoal**, graphite, and the electrophotographic developer powders listed in Table 44. This table gives the compositions of the various developers listed above and the sources of the materials used.

Some preliminary work has been done to further improve grain quality and increase image density through the use of carbon blacks. These were chosen both because of their blackness and their small particle size. The carbon blacks are available with an average particle size of less than one-half micron. The powders listed above have particle sizes greater than one micron. The main difficulties involved in the use of the fine carbon blacks are their poor dry-flow characteristics and their strong tendency to agglomerate.

* KJDD-19, National Starch Products, 270 Madison Ave., New York 16, New York.

** Pulverized Charcoal, George Oravetz & Son, P.O. Box 524, Auburn, Washington. This material was ball milled in our laboratory for sixteen hours before use.

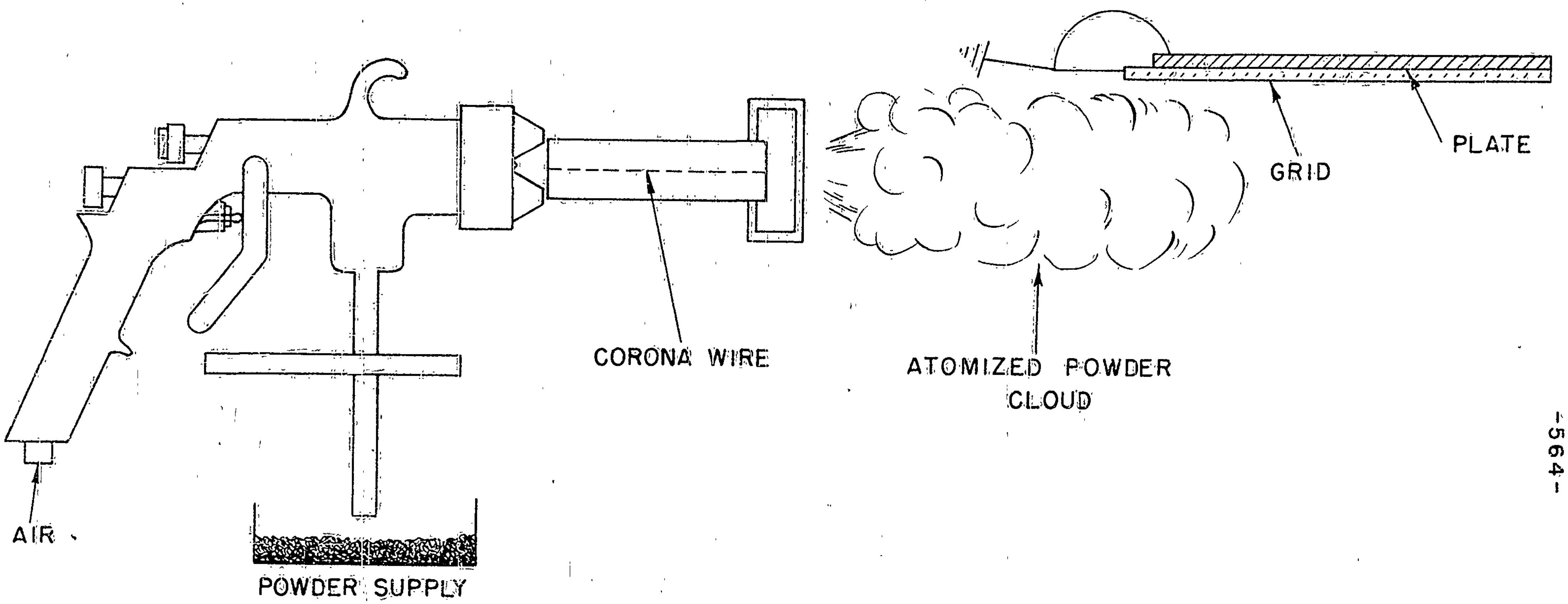
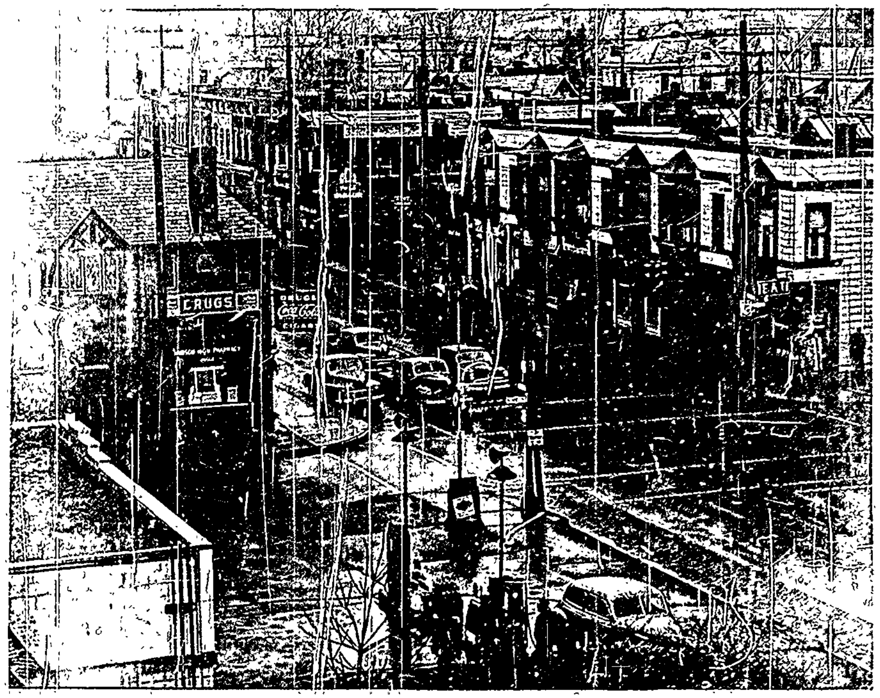


FIGURE 172. SKETCH OF POWDER-SPRAY DEVELOPING APPARATUS

0-14752

SILVER HALIDE SUBJECT



ORIGINAL SUBJECT

FIGURE 173. ELECTROPHOTOGRAPHIC PRINTS DEVELOPED WITH BALL-MILLED CHARCOAL, USING PAINT-SPRAY GUN

68578

TABLE 44. DEVELOPER POWDERS USED WITH POWDER-SPRAY TECHNIQUE

Powder Number	Composition (by weight)
A1-20	80 per cent Amberol F-71, 20 per cent Raven Bead Carbon Black
4-25-49-1	55 per cent No. 2100 Super Beckacite, 35 per cent Zein A, 10% Pigment Deep Black, Extra Conc.
5-1-49-1	55 per cent Amberol F-71, 35 per cent Zein A; 10 per cent Raven Bead Carbon Black Conc.
5-2-49-1	55 per cent Amberol F-71; 35 per cent Zein A; 10 per cent Rol-Up Ink
5-9-49-1	45 per cent Rosin, 45 per cent Zein A, 10 per cent Raven Bead Carbon Black
5-10-49-1	45 per cent Synthetic Copal Ester, 45 per cent Zein A, 10 per cent Raven Bead Carbon Black.

Manufacturers

Amberol F-71 - The Resinous Products & Chemical Co, Philadelphia, Pa.

Raven Bead Carbon Black- Binney & Smith Co, New York, N. Y.

No. 2100 Super Bechacite - The Reichhold Chemical Co., Detroit, Mich.

Pigment Deep Black, Extra Conc.- General Dyestuff Corp., N. Y., N. Y.

Zein A.- Corn Products Sales Co., Pittsburgh, Pa.

Synthetic Copal Ester - The Reichhold Chemical Co., Detroit, Mich.

Other types of spray devices have been used successfully. These include the fly-spray type of gun and the common medicinal atomizer. The medicinal atomizer has particular advantage when it is desired to use the fine carbon blacks, as it premixes the air and powder in the reservoir before passing them through the nozzle. This almost entirely eliminates the tendency of the carbon particles to agglomerate. A reproduction of a silver halide photograph using the medicinal atomizer* and Kosmos BB Carbon Black** is shown in Figure 174.

The process has also produced pictures similar in quality to that shown in Figure 174, when the plate to be developed is placed on the standardized 5- by 6- by 2-1/2-inch dust box, by blowing the powder spray into the box through a small hole. A tube, one-half inch in diameter, with a 0.003-inch corona wire three inches long, mounted in front of the entrance hole, provided the powder-charging means. A negative potential on the wire of between 3,000 and 4,500 volts was used. The medicinal atomizer can be used as the spray source. An enclosed and compact bulb or bellows device, which blows the atomized spray into the box and also collects it through an exit orifice in the box, could conceivably be applied to the present dust box. Such a design should be readily adaptable to the electrophotographic camera.

Liquid-Spray Development

The only experimental work on liquid-spray development since the work reported in Quarterly Progress Report No. 6 (pages 497-502) was

* Nyad Atomizer P-651, distributed by Nyal Service Drug Stores.

** United Carbon Company, Charleston, West Virginia.

Other types of spray devices have been used successfully. These include the fly-spray type of gun and the common medicinal atomizer. The medicinal atomizer has particular advantage when it is desired to use the fine carbon blacks, as it premixes the air and powder in the reservoir before passing them through the nozzle. This almost entirely eliminates the tendency of the carbon particles to agglomerate. A reproduction of a silver halide photograph using the medicinal atomizer* and Kosmos BB Carbon Black** is shown in Figure 174.

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Liquid-Spray Development

The only experimental work on liquid-spray development since the work reported in Quarterly Progress Report No. 6 (pages 497-502) was

* Nyad Atomizer P-631, distributed by Nyal Service Drug Stores.
** United Carbon Company, Charleston, West Virginia.

FIGURE 174. ELECTROPHOTOGRAPHIC PRINT OF SILVER HALIDE SUBJECT DEVELOPED USING KOSMOS BB CARBON BLACK AND NYAL ATOMIZER

68579

concerned with the search for a better flowing suspension of lampblack in acetone. The simple slurry of lampblack in acetone that produced the fine-grain pictures had a tendency to clog the fine orifice of the spray gun. It was found that adding a stabilizing agent and ball milling the mixture produced a suspension that did not clog the gun.

The formulation of this lampblack-in-acetone suspension is as follows:

8 per cent Monsanto No. 2 Lampblack*
78 per cent C.P. Acetone
4 per cent Collodion
10 per cent water

A 400-gram quantity of this mixture was ball milled eight hours in a two-quart, crockery ball mill containing one quart of 5/8-inch steel balls.

ADHESIVE TRANSFER AND FIXING

P. G. Andrus

The work reported on adhesive transfer in Quarterly Progress Report No. 6 (page 503-504) indicated that adhesive transfer could be better than the usual electrostatic method of transferring. It was also found that transferring by exposing the paper to a corona discharge generally caused breakdown of the plate. Although there are indications that the interposition of a sheet of a good insulating material between the corona and the paper might eliminate this breakdown, it was felt important to investigate thoroughly the possibility of an adhesive-tape transfer and fixing method.

* Monsanto Chemical Company, New York 17, New York

A successful method for transferring and fixing powder images using adhesive tapes has been developed. The method involves commercially available tapes and a relatively simple mechanism to produce the final print from the developed electrophotographic plate. The present minor difficulties of the process appear to be such as can be eliminated by feasible modifications of the adhesive tapes.

The search for transparent adhesive tapes which can be used to cover, and thus fix powder images, which have been electrostatically transferred to ordinary paper, has been unsuccessful. No tape has been found which will fix large-area, heavy-powder deposits to ordinary paper.

Printmaking Procedure

The method of making a print using pressure-sensitive adhesive tapes is basically as follows. The tape used for transferring the image is pressed onto the powder image on the developed electrophotographic plate using a rubber roller. As the tape is then pulled free of the plate, most of the powder adheres to the adhesive surface. A transparent pressure-sensitive tape is applied to cover the powder image on the original piece of tape, again by pressure between rubber rollers. The powder image is thus sandwiched between two adhesive layers.

Several pressure-sensitive adhesive tapes were tested in the procedure described above. The tapes were all of the "Scotch" brand made by the Minnesota Mining & Manufacturing Company, St. Paul, Minnesota. Tapes Nos. 250, 471, 600, 610, 700, 750, and 800 were all found to remove most of the powder from a plate under pressure application. Tapes Nos.

250, 471, 700, and 750 required more pressure than the others, apparently because the adhesive surface was relatively rough and its depressions had to be forced down to touch the powder. All of the tapes tended to remove selenium from plates which had poor adhesion between the selenium and backing material. However, on most of the plates tested, none of the selenium could be removed by any of the tapes.

There was considerable variation in other pertinent physical characteristics of the tapes. These characteristics are rated qualitatively in Table 45. This tabulation indicates that Tape No. 800 probably has the most desirable adhesive properties of all the tapes tested. However, Tape No. 700 has the singular advantage of being readily obtainable in a dead-white color. For this reason, the No. 700 tape is recommended when prints are to be made directly, and the No. 800 when transparencies are satisfactory.

The complete printmaking procedure requires that a transparent cover material be pressed onto the surface of the transferred powder image to fix and protect it. Of all the transparent-tape materials tried (including plain cellulose acetate sheeting and Stik-on No. 150*) "Scotch" brand Tape No. 800 gave the least trouble with regard to bubble and wrinkle formation.

The apparatus used to test the possibilities of the adhesive-transfer method consisted basically of two rubber rollers mounted in wringer-roller fashion. These pressure rollers were arranged so that the force between the rollers could be easily varied by the adjustment of weights on a lever arm. The apparatus sketched in Figure 175 actually

* Eugene Dietzgen Company, Chicago, Illinois.

TABLE 45. TRANSFER CHARACTERISTICS OF PRESSURE-SENSITIVE ADHESIVE TAPES

Tape Number	Transfer Characteristics			
	Transfer Pressure(1)	Unwind Force(2)	Stretch(3)	Color on Transparency(4)
280	High	Medium High	Low	Tan Opaque
471	High	Medium High	High	Cloudy Yellowish
600	Medium	High	Medium	Yellowish
610	Medium	High	Medium	Yellowish
700	High	Medium High	Low	White Opaque
750	High	Medium	Low	Eggshell Opaque
800	Medium	Medium	Medium	Transparent, Slightly Cloudy

(1) Relative pressure required to obtain uniform transfer of the powder image. High pressure is of the order of 300 pounds per square inch.

(2) Relative force required to unwind tape from its supply roll.

(3) Relative stretch of tape under equal tension.

(4) The color or degree of transparency of the tapes that are nearest to white or transparent.

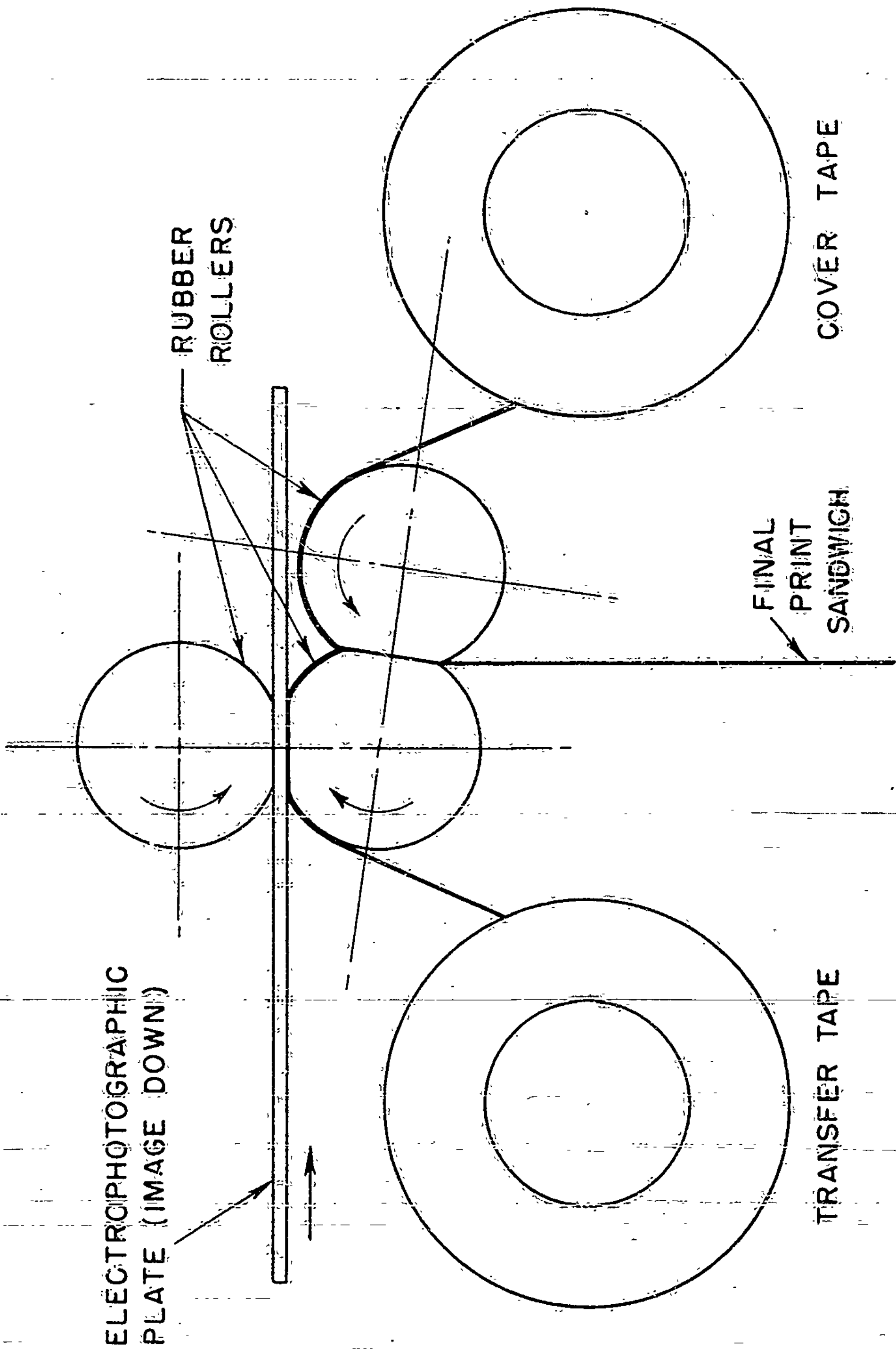

FIGURE 175 ADHESIVE TRANSFER AND FIXING APPARATUS

0-14753

had two pressure rollers bearing on a third roller, so arranged that the image could be transferred and fixed in one continuous operation. The transfer and fixing operations were carried out simply by pulling carefully on the final print sandwich. The rollers used in the apparatus were 1-1/8 inches in diameter. Three roller hardnesses were tested, two of rubber and one of steel. The rubber rollers (3/16 rubber on 3/4-inch steel cores) had rubber durometer hardnesses of 35 and 75 (Rex gauge).

The roller hardness and pressures needed were tested by transferring powder images with the No. 700 opaque "Scotch" tape and fixing the image with the No. 800 "Scotch" tape. The rubber rollers having a hardness of 75 (Rex gauge) gave satisfactory prints when a force of 50 pounds per linear inch of roller was used for both the transfer and fixing operations. Forces less than 50 pounds per linear inch resulted in a greatly increased number of tiny air pockets resulting from the rough texture of the adhesive on the tapes. These tiny air pockets were not entirely removed even at a force of 50 pounds per linear inch, and forces greater than 50 pounds per linear inch did not greatly decrease the number of air pockets. The softer rubber rollers required much more force to produce a print comparable to that produced with the harder rubber rollers. The steel rollers produced satisfactory prints at 50 pounds per linear inch and even at somewhat smaller forces, except that lack of plate flatness or nonuniformity in tape thickness prevented the roller from exerting sufficient force over all of the plate.

The tests of the transfer and fixing operations described above were carried out at tape speeds of about one inch per second. This speed did not appear to be critical, but higher speeds did result in an increased number of air pockets and an occasional wrinkle. This trouble may have been due to the method of moving the tape, i.e., pulling on the sandwiched end.

Special Transfer and Fixing Tapes

The work that has been carried out on adhesive transfer to this date has led to the following conclusions about the characteristics of adhesive tapes to be used for transferring powder images.

(1) High-tack adhesive tapes are not necessary to uniformly remove powder from an electrophotographic plate. The highest tack tapes tested did not remove a noticeably greater amount of powder than the nearly tack-free gelatin-coated paper. (Use of gelatin-coated paper for transferring powder images is described in Quarterly Progress Report No. 6, page 504.) Furthermore, high-tack tapes require an undesirably large force to be stripped from the plate and have a greater tendency to remove selenium from the plates. For these reasons, it is believed that a low-tack tape is desirable for adhesive transfer.

(2) The most noticeable imperfections in prints made using adhesive transfer and fixing result from nonuniformity in the surface of the adhesive. This nonuniformity may be either a textured or rough surface prepared intentionally, or may result from inclusion of air bubbles when the tape is first wound into a roll. A pressure-sensitive adhesive tape having a carefully rolled, smooth-surfaced adhesive is desirable for adhesive transfer.

The Minnesota Mining & Manufacturing Company has undertaken to produce samples of special tapes having characteristics nearer the desirable ones described above. These tapes are expected to be modifications of an easily strippable protective-film tape having an extremely low tack, low adhesion, low unwind force, and a smooth adhesive surface. It is expected that the tapes can be furnished in either transparent or white opaque form. First samples of these special tapes are expected to arrive early in March.

EXPERIMENTS ON VACUUM-EVAPORATED SELENIUM PLATES

J. L. Stockdale and O. A. Ullrich

Preparation and Testing of Selenium-Coated Plates

Work on the preparation of selenium-coated electrophotographic plates during this last quarter was devoted principally to making a large number of plates for use in experiments on the development and transfer processes. These plates were prepared using the techniques and conditions found to produce the plate characteristics which are most desirable for the particular development conditions used at the present time.

Measurements of potential-decay characteristics and selenium thickness were made on plates selected at random from this large number. All plates were thoroughly tested for image-producing qualities. The plates were also subjected to a severe test for the adhesion of the selenium to the backing plate.

All of these plates tested had electrical and printmaking characteristics which were so similar as to make one plate indistinguishable from another in these tests. A few plates, less than 20 per cent, failed to some extent in the adhesion test.

A comparison of potential-decay curves of old and new plates was also made and is reported here.

Routine Preparation of Plates

Approximately 70 plates were prepared under standardized conditions with selenium films 50 microns thick. They were made according to the specifications set forth in the section on "Engineering Information" on page 606 in the ~~Appendix of this report~~.

Approximately 50 of these plates were prepared using an array of selenium-evaporation boats which gave a deposit on the plate about 20 per cent thicker in the center than near the edges. This nonuniformity of selenium thickness was corrected for the rest of the plates by adjusting the filament configuration to give a deposit which was uniform over the four- by five-inch plate to within plus or minus two per cent. The filaments were sufficiently loaded with selenium to prepare each plate in a single evaporation.

The choices of 50-micron thickness and 70 to 74°C. preparation temperature were made on the following basis. It was found that plates with selenium films less than 20 microns thick could not be charged to a useable potential without suffering electrical breakdown. Thicker films of selenium permit the acceptance of higher plate potentials without breakdown. However, another factor limits the maximum film thickness to 50 microns. This factor is residual potential (the potential which remains on the plate after light exposure) and is a minimum for plates which are held between 70 to 75°C. during preparation. A 50-micron plate prepared at these temperatures can sustain 275 volts without breakdown and its residual potential does not exceed the maximum allowable value of from 5 to 10 volts.

More and more evidence points to the fact that low relative humidity in the room housing the vacuum evaporation apparatus is a significant factor in obtaining slow, dark-decay rates. The humidity for the period during which these plates were prepared was generally well under 30 per cent.

Image-Quality Tests

Image-quality tests on these plates made during the last quarter have been very extensive. They include inspection of the image for the presence of:

1. Powder-deficient areas greater than one-half millimeter in diameter (indicating gross breakdown of the selenium)

2. Powder-deficient spots less than one-half millimeter in diameter (indicating start of breakdown)

3. Graininess, or gross agglomeration of powder in areas which should be uniform in tone or density (indicating breakdown)

4. Nonuniform powder deposition in large areas that should be uniform in tone or density (indicating uneven acceptance of potential or uneven dark-decay rate)

5. Powder deposited in highlights, generally irregular (indicating unduly high, residual plate potential)

6. Water marks or cleaning streaks, resulting from poor cleaning of the backing material prior to deposition of the selenium.

The plates made according to the specifications given in this report do not give rise to any of the defects listed above if they are not charged to more than 275 volts in use.

Potential-Decay Measurements

Measurements of dark-decay rates for positive charging were carried out on plates chosen at random from this latest group, using both the point-probe (Cambridge) electrometer and on the vibrating-probe electrometer. With the point-probe electrometer, the duration of the dark-decay test was ten minutes, and the decay rate started at about two volts per minute and gradually decreased. An initial potential of 200 volts was used. With the vibrating-probe electrometer, the duration of the test was 50 minutes, and here the decay rate was very nearly 1 volt per minute. These results are in good agreement, particularly when one remembers that dark-decay rates are always faster at the beginning of the decay period. It is impossible to define this decay rate in the same percentage terms as has been used in other cases, since the definition of per cent decay rate involved a time interval only from 20 to 200 seconds after charging.

A Test of Selenium Adhesion to the Backing Plate

No quantitative test of selenium adhesion to the backing plate has been made. Only the qualitative methods of normal use and resistance to stripping with Scotch tape and resistance to normal wear have been applied previously. The advent of the adhesive-transfer method has introduced another qualitative test, but one which is much more severe than the first two mentioned. In spite of the severity of this new test, less than 10 per cent of the plates show insufficient adhesion of the selenium to the backing plate.

The adhesive-transfer operation, as discussed in detail starting on page 570 of this report, involves two steps which give the selenium film severe treatment. The first of these is the force of the hard-surfaced, rubber, pressure roller against the plate as the tape is applied. This may damage the plate if dirt or grit particles are present. The second step in the transfer operation which gives the plate a severe treatment is the peeling of the adhesive tape from the plate after transfer. This tape not only is pressed against the whole plate surface more firmly than in the ordinary Scotch-tape adhesion test, but it has considerably more tack than ordinary Scotch tape.

The degree of adhesion which can be attained between the selenium and the brass backing material has been clearly demonstrated in several instances. These were cases in which relatively large areas of the selenium itself actually split apart - one side of the selenium adhering to the brass, and the other side adhering to the transfer tape.

Miscellaneous Potential-Decay Measurements

Dark-Decay Rates at Reduced Charging Potentials

The vibrating-probe electrometer was used to measure the decay characteristics of brass-backed, selenium plates when charged to a potential well below the maximum which they can accept. The potential-control-grid unit which was built for the vibrating-probe electrometer was used to charge the plates. Both the dark- and light-decay characteristics were practically the same in this case as when the plates were charged to their maximum with the open charging needle. The only difference noted was the fact that the dark-decay rates increase as the potential to which the plates are charged is decreased. The curves in Figure 176 are typical examples of this effect. The absolute potential drop is fairly constant for each of these curves for any given time interval. This suggests the possibility that the decay curve is a combination of two effects, one nearly logarithmic and which predominates at the higher potentials, and the other linear and which predominates at the lower potentials.

Remeasurement of Decay Characteristics

The dark-decay rates of several old plates were remeasured and compared with similar measurements taken when the plates were new. These results are as follows:

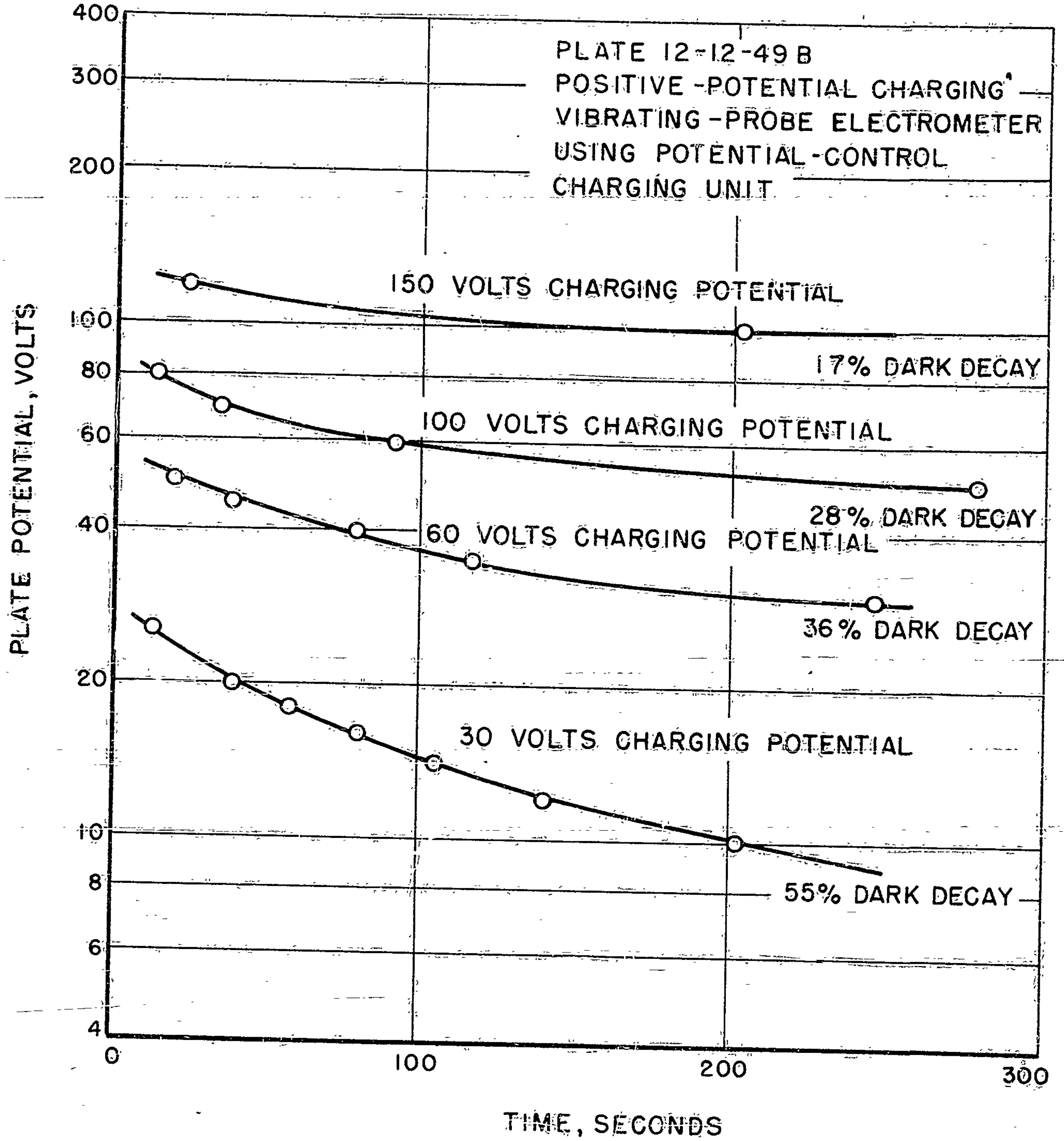

FIGURE 176. CHANGE IN DARK-DECAY RATE WITH CHANGE IN CHARGING POTENTIAL

0-14754

Plate Number	Backing Material	First Measurement Date	First Measurement Per Cent Dark Decay	Recent Measurement Date	Recent Measurement Per Cent Dark Decay
7-7-49B	Aluminum and MgF_2	7-8-49	40	2-2-50	26
9-26-49B	Brass	9-26-49	32	2-2-50	16
11-18-49A	Brass	11-18-49	55	2-2-50	20

In each case, the dark decay has become decidedly slower. It is not known whether this effect is due to a change in the selenium itself, a change in the interface between the selenium and the backing material, or simply a change in the moisture content in the selenium.

Effect of Cleaning Techniques on Plate Properties

The cleaning procedure currently used in preparing the brass plate for coating with selenium, involves the use of Gold Seal Glass Wax (composition given on page 511 of Quarterly Progress Report No. 6; use described in the section entitled "Engineering Information for Camera Design" on page 606 in the Appendix of this report). Some tests were made to determine what component or components of this commercial product are responsible for its value in cleaning the brass plates. These tests, although they are not complete, have shown that the presence of the petroleum fraction is undoubtedly the most important single factor in producing slow, dark-decay rates. This component has no apparent bad effect in increasing the residual potential or decreasing adhesion.

The virtue of the Glass Wax treatment is not to improve adhesion or improve image quality directly, but only to cause the plates to have slow, dark-decay rates for positive-potential charging.

The composition of Glass Wax, as presented in the above reference, is given as 75 per cent water, 15 per cent petroleum fraction, 7.5 per cent abrasive, ammonia, emulsifier, and coloring agent.

This investigation involved comparing dark-decay rates, residual potential, image quality and adhesion for plates prepared with the standard technique and for plates in which the use of Glass Wax was eliminated. The following procedures were substituted for the Glass Wax step in cleaning:

1. Scrub with cotton saturated with a water suspension of rouge
2. Scrub with Bon Ami*
3. Treat with a dilute ammonia solution
4. Swab with cotton saturated with a solution of paraffin in benzene and buff to high polish with dry cotton swab
5. No treatment substituted for Glass Wax cleaning.

In no case did plates given these treatments have poor adhesion, poor image quality or high residual potentials. The only differences that appeared were in the rate of positive dark decay. Rouge, Bon Ami, ammonia, and no treatment gave plates with decay rates twice as fast as when the Glass Wax step was used. The paraffin-in-benzene treatment gave plates with decay rates one-half as fast as Glass-Waxed plates. Apparently the petroleum fraction, in the form of paraffin, is an important constituent for this purpose. The presence of the paraffin

* Manufactured by The Bon Ami Company, New York, New York.

layer gives rise to a small residual potential, as did the Glass Wax cleaning. As this residual potential is less than five volts, unless the paraffin film is too thick, it does not cause trouble in the process.

PHOSPHOR-COATED ELECTROPHOTOGRAPHIC PLATES

S. J. Czyzak and W. H. Zolinski

Summary of Results

In Quarterly Progress Report No. 6, page 519, it was recommended that controlled experiments be made on phosphor film thickness, and that various types of phosphors be investigated for electrophotographic use. In addition to the above recommendations, experiments were conducted to determine the effect of coating plates by spray or dipping, the effect of particle size of phosphor, the effect of binder composition and content in spray- or dip-coated plates on electrical and photographic properties.

In the investigation of the above-mentioned factors, the following points were observed:

(1) The graininess of an electrophotograph is directly proportional to the particle size of the phosphor, i.e., the smaller the particle size the less the graininess.

(2) The faithfulness of tonal rendition is improved by increasing the thickness of the phosphor deposit. However, when the deposit exceeds 0.007 inch in thickness, the tone does not continue to improve.

(3) Background was observed in all electrophotographs; however, it could be eliminated to a great extent by using a development grid with a potential.

(4) Polishing the phosphor surface after spraying or dipping does not improve any of the qualities discussed in (1), (2), and (3) above, indicating that none are dependent on the smoothness of the surface.

(5) Ball milling a phosphor with a particle size of 50 microns to a size of approximately one micron, elimininates the fluorescence of the phosphor, materially alters the electrical properties, but does improve the grain texture.

(6) The manner in which the phosphor is deposited, i.e., spray, dip, or flow, has no effect on the electrical or photographic properties, and, since the simplest way of depositing the phosphor on the plate is by dipping, this method is recommended.

(7) From the series of phosphors examined, three possess good electrical and photographic properties. They are the following zinc sulphide: cadmium sulfide phosphors F-2032 (RCA) and No. 1200 (Du Pont) and the zinc sulfide phosphor 2225 (New Jersey Zinc Company). However, since the 2225 produces a photograph that has a finer tone quality than the others, it is the best phosphor for this application.

Experimental Work on Phosphor Plates

The following phosphors were used for electrophotographic research:

From RCA	F-2039 (Zn:CdS)
	F-2032 (ZnO)
	F-2046 (ZnS)
From E. I. Du Pont Co.	511 (ZnO)
	601 ($ZnSiO_2$)
	1200 (Zn:CdS)
	501 ($CaWO_4$)
From New Jersey Zinc Co.	2225 (ZnS:CdS)
	2330 (ZnS)

These phosphors were used as received, except in one experiment where some of the F-2039 was ball milled to determine the amount of damage such treatment would do to a phosphor.

In order to eliminate unsatisfactory phosphors as quickly as possible, the phosphor plates were prepared by making a 1:1 mixture by volume of the particular phosphor with DC-996 silicone resin. This mixture was spread over a four- by five-inch aluminum plate by means of a doctor blade, producing a deposited strip two by five inches in dimension. All the plates were tested for physical and electrical properties. If, however, the phosphor did not show any desirable electrical properties, no photographic tests were made on it.

Phosphor-coated plates made by the use of the doctor blade were of two thicknesses, 0.005 inch and 0.008 inch, and were five inches by two and one-half inches in area. As shown in Figure 177 and 178, the phosphors F-2039 (Zn:CdS from RCA), 1200 (Zn:CdS from DuPont) and 2225 (ZnS from New Jersey Zinc Company) had good electrical properties, that is, slow, dark-decay rates, and fast, light-decay rates. Electrophotographic images were made with the above doctor-blade treated plates and the

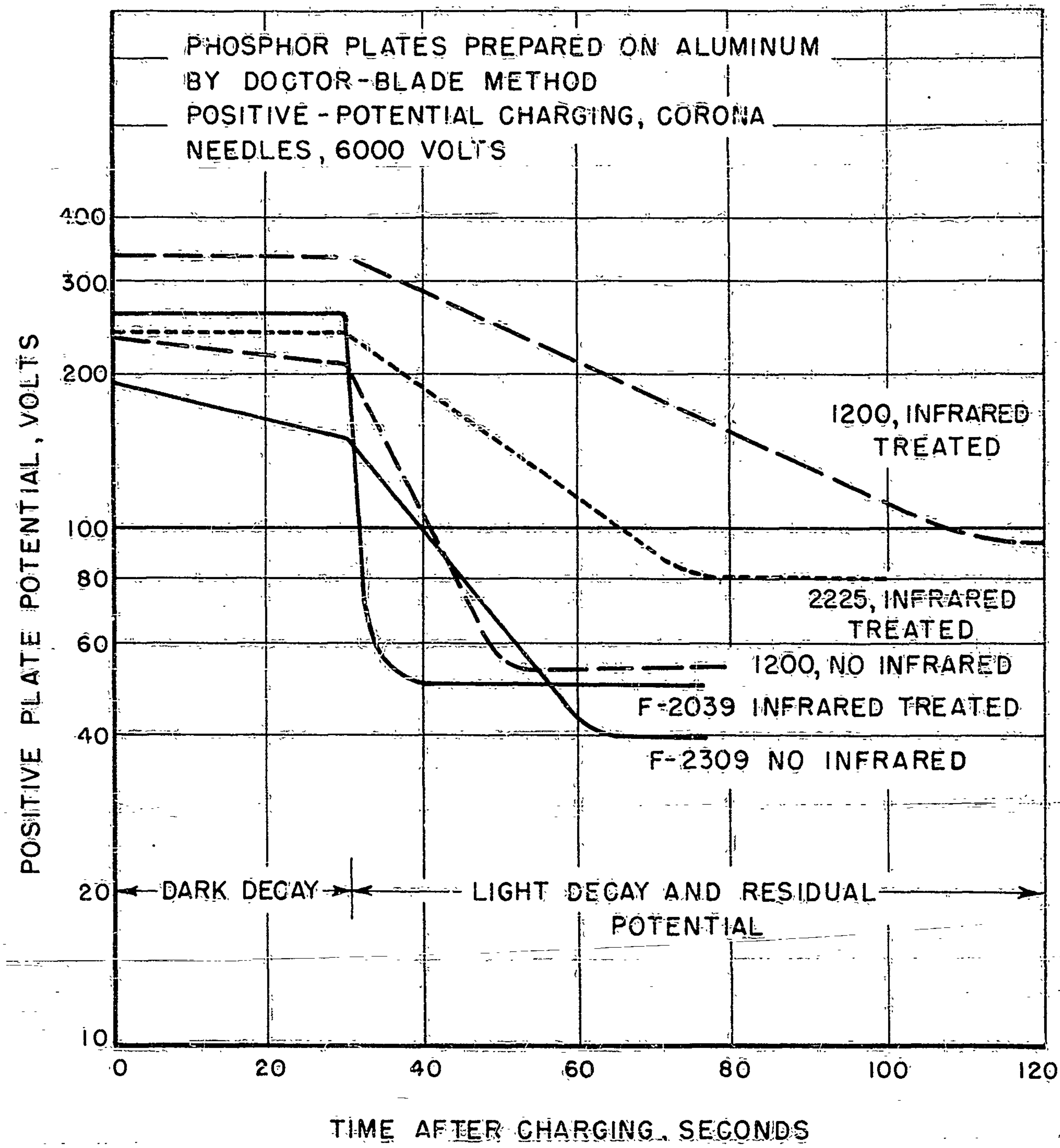

FIGURE 177. COMPARISON OF POTENTIAL-DECAY CHARACTERISTICS FOR THREE PHOSPHORS, WITH AND WITHOUT INFRA-RED TREATMENT

0-14755

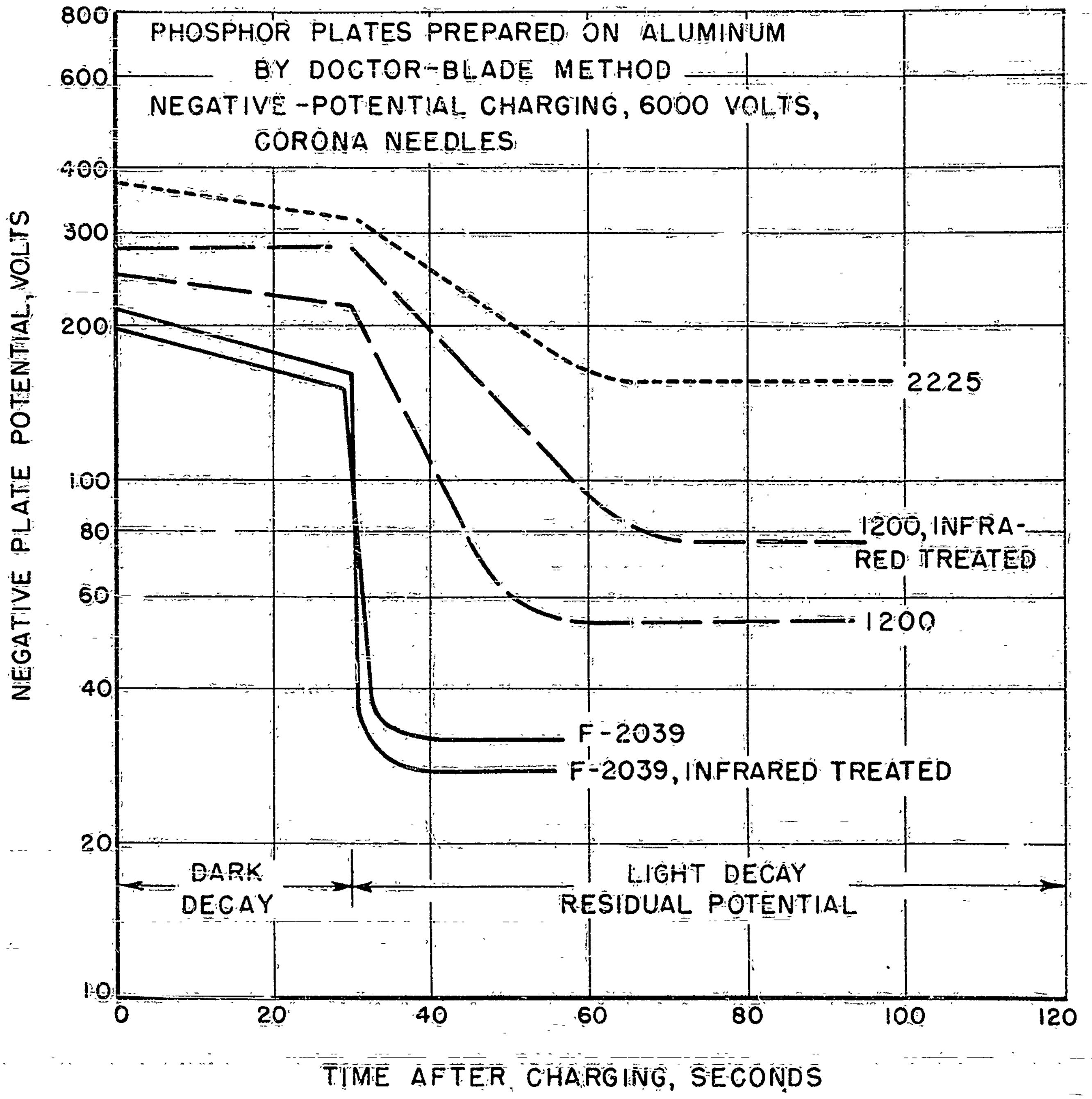

FIGURE 178. COMPARISON OF POTENTIAL-DECAY CHARACTERISTICS FOR THREE PHOSPHORS, WITH AND WITHOUT INFRARED TREATMENT

D-14756

F-2039 and 2225 phosphors appeared to give the best photographs. Phosphors other than F-2039, 1200, and 2225 did not have satisfactory electrical or photographic properties, so no further work was done on them.

As a result of these preliminary findings, the following investigation was conducted on the three most promising phosphors (F-2039, 1200, and 2225):

(1) The phosphors were sized to determine the effect of particle size on the electrical and photographic properties.

(2) The aluminum plates (four by five inches) were coated with phosphors by two other methods, dipping and spraying. The object was to observe the effect on the properties caused by the method of preparing the plates. The dipped plates were withdrawn from the solution at the rate of one inch per minute and the sprayed plates were given ten passes of the spray gun. The gun was placed 6-3/4 inches from the plate, the air pressure was 40 pounds per square inch, and the plate moved past the gun at a rate of 14 inches per second.

(3) The plates were tested for electrical properties and, using these data, photographs were developed.

(4) The photographs were printed using adhesive transferring and fixing as described in Progress Report No. 6, page 503.

(5) The F-2039 phosphor was ball milled for a period of four hours to determine how seriously the properties of the phosphor are affected when the particle size is reduced by this method. Previously, all phosphor plates had been prepared by spraying. Since, in the

preliminary tests, the electrical and photographic properties had not been altered by the doctor-blade method of coating the aluminum plates, only one plate was prepared by spraying to serve as a check on the doctor-blade method. Further, since the 2225 phosphor was not available and only a small quantity was on hand, it was used very sparingly to serve as a check on the data obtained in detail on the F-2039 phosphor. Tables 46 and 47 show the coating thickness and charging, exposure, and development conditions used, respectively, for the experiments outlined above. Figures 179 through 183 show the electrical properties that were obtained. These figures show dark-and light-decay curves and residual potentials for both positive and negative charging. They also show the effect of an infrared heat treatment on the potential characteristics of these phosphor plates. This infrared treatment consists of exposing the plates to a resistance-heating unit for ten minutes which raises the plate temperature to over 100°C.

Discussion of Experimental Results

From the graphs in Figure 177 and 178, it can be seen that the F-2039 phosphor has the fastest light decay. It is better than 1200 or 2225 by approximately an order of magnitude. In general, the maximum charge accepted by the various phosphors is approximately the same for the same thickness of phosphor coating (Figure 177 and 178); when plates are treated with infrared before exposure, the maximum potential is somewhat higher. Further, it can be seen that for the F-2039 and 2225 phosphors, the light decay is approximately the same regardless of

TABLE 46. PHYSICAL CHARACTERISTICS OF PHOSPHOR COATINGS

Plate Number	Phosphor Used	Method of Coating	Number of Dips or Sprays	Coating Thickness, Inch	Range of Particle Size of Phosphor, Microns
36	F-2039	Dipping	1	0.0035 ± 0.0002	5.0 to 50
37	F-2039	Dipping	2	0.0070 ± 0.0002	5.0 to 50
39	F-2039	Dipping	3	0.0110 ± 0.0002	5.0 to 50
42	F-2039	Dipping	4	0.0145 ± 0.0003	5.0 to 50
43	F-2039	Spraying	10	0.0030 ± 0.0002	5.0 to 50
—	2225	Spraying	10	0.0030 ± 0.0002	0.5 to 5.0
48	2225	Doctor Blade	--	0.0050 ± 0.0005	0.5 to 5.0
26	F-2039	Doctor Blade	--	0.0080 ± 0.0005	5.0 to 50
1	1200	Doctor Blade	--	0.0080 ± 0.0005	Above 75
51	F-2039*	Doctor Blade	--	0.0050 ± 0.0005	0.5 to 5.0

TABLE 47. CHARGING, EXPOSURE AND DEVELOPMENT CONDITIONS FOR PHOTOGRAPHIC TESTS

Plate Number	Method of Exposure	Charging Conditions, Volts		Exposure-Box Conditions		Development Conditions			Remarks
		Corona Wire	Grid	Voltage on Lights	Time, Sec.	Powder	Voltage on Grid	Brush Strokes	
36	Carlson	-6000 +6000	-90 +90	90 90	0.5 0.5	AG-1 Alj	0 0	70 70	Polarity of charging produces no appreciable difference in image appearance
43	Carlson	+7000	+90	90	0.5	Alj	0	70	
37	Carlson	-6000 +6000	-90 +90	90 90	0.5 0.5	AG-1 Alj	0 0	70 70	Ditto "
39	Carlson	-7000 +7000	-90 +90	90 90	0.5 0.5	AG-1 Al-j	0 0	70 70	" "
38a	Carlson	+7000	+90	90	0.5	Al-j	-45	70	Background diminished
42	Carlson	-7000	-90	90	0.5	AG-1	0	70	
—	Carlson	+7000	+90	90	0.5	Alj	0	70	
48	Carlson	+7000	+90	90	0.5	Alj	0	70	
26	Carlson	-7000	-90	90	0.5	AG-1	0	70	

TABLE 47. CONTINUED

Plate Number	Method of Exposure	Charging Conditions, Volts		Exposure-Box Conditions		Development Conditions			Remarks
		Corona Wire	Grid	Voltage on Lights	Time Sec.	Powder	Voltage on Grid	Brush Strokes	
1	Carlson	+7000	+ 90	90	0.5	Alj	-90	70	Background diminished
51	Carlson	+7000	+90	90	0.5	Alj	0	70	
48	Kallman	+7000	+90	90	1.0	Alj	0	70	
--	Kallman	+7000	+90	90	1.0	Alj	0	70	
36	Kallman	-7000	-90	90	1.0	AG-1	0	70	No photographs obtained. Exposure conditions had to be altered to obtain satisfactory photographs.
39	Kallman	-7000	-90	90	1.0	AG-1	0	70	
42	Kallman	-7000	-90	90	1.0	AG-1	0	70	

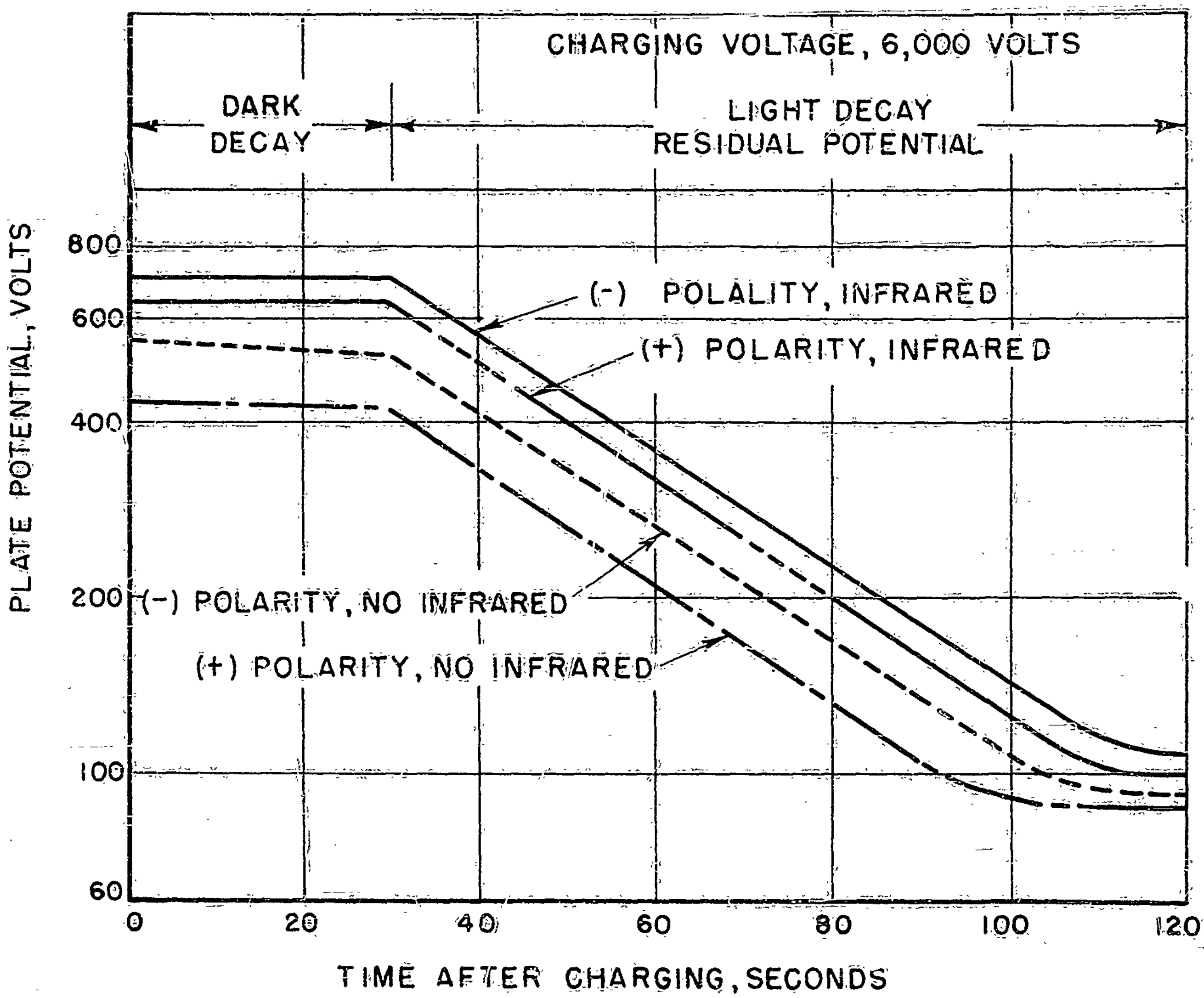

FIGURE 179. POTENTIAL-DECAY CHARACTERISTICS FOR SPRAY-COATED PHOSPHOR PLATE 2225, 0.0035 INCH THICK

0-14759

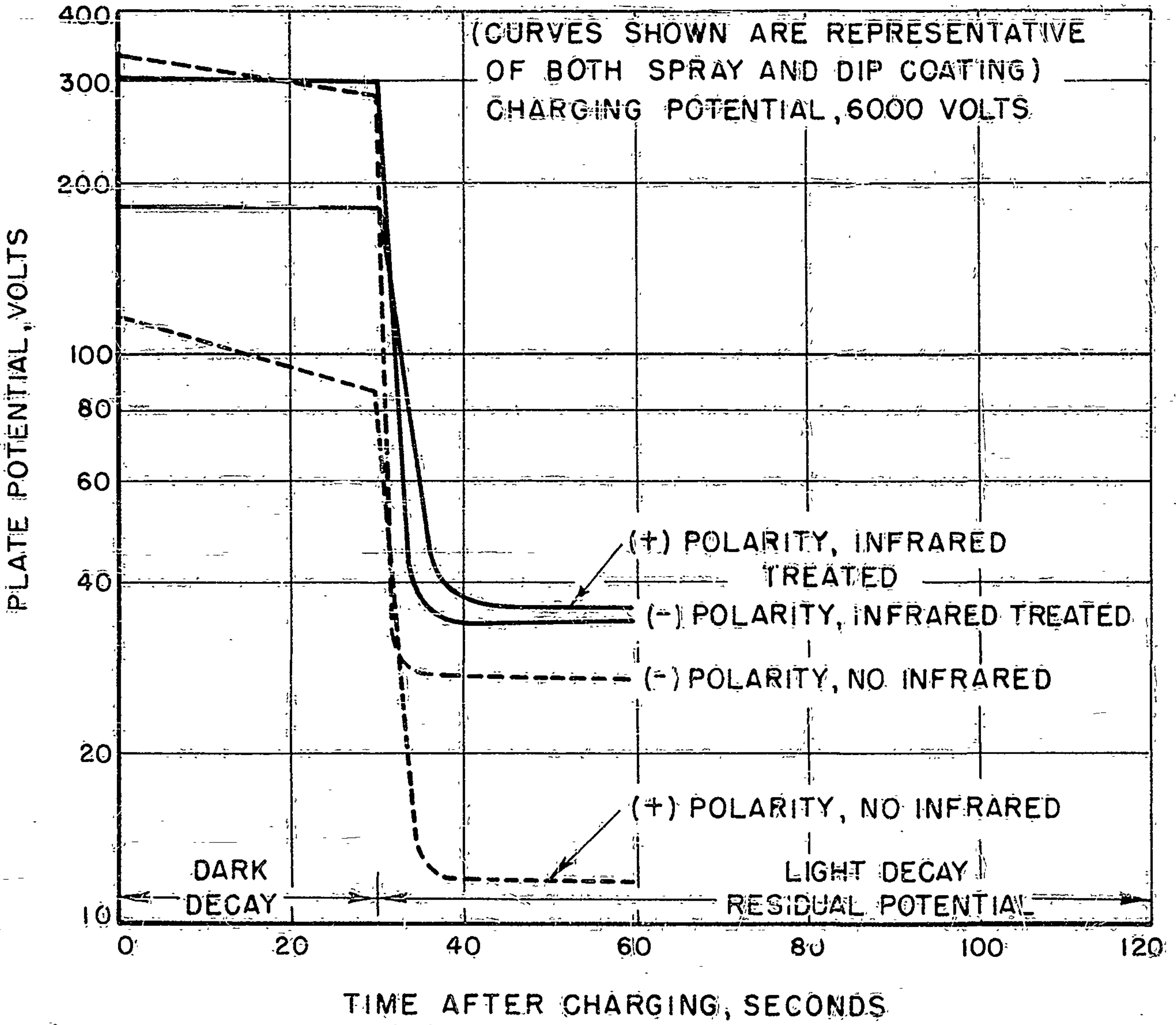

FIGURE 180. POTENTIAL-DECAY CHARACTERISTICS FOR DIP-COATED AND SPRAY-COATED PHOSPHOR PLATES F-2039, 0.0035 INCH THICK

0-14758

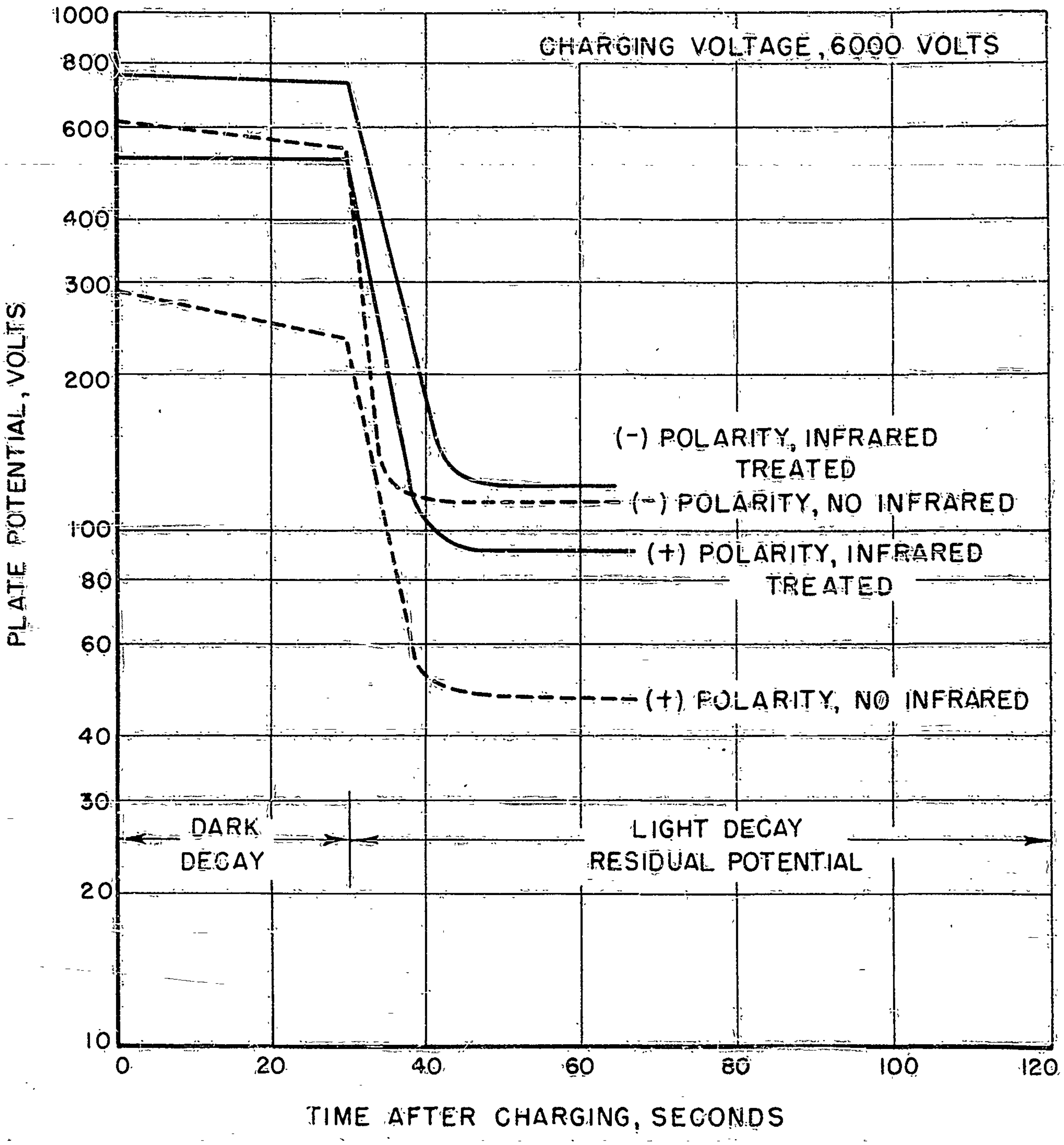

FIGURE 181. POTENTIAL-DECAY CHARACTERISTICS FOR DIP-COATED, PHOSPHOR PLATE F-2039, 0.007 INCH THICK

0-14759

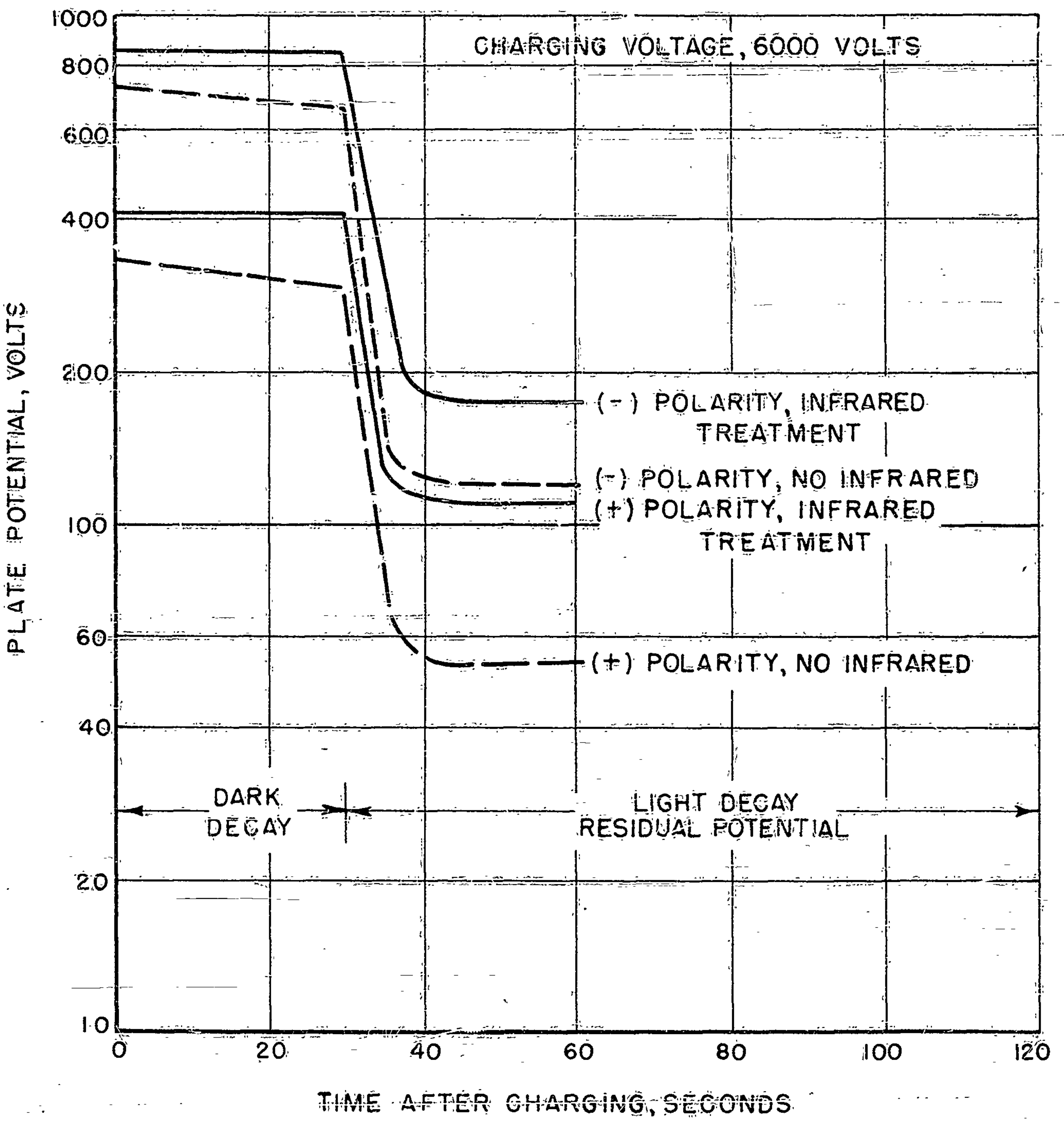

FIGURE 182. POTENTIAL-DECAY CHARACTERISTICS FOR DIP-COATED, PHOSPHOR PLATE, F-2039, 0.011 INCH THICK

0-14760

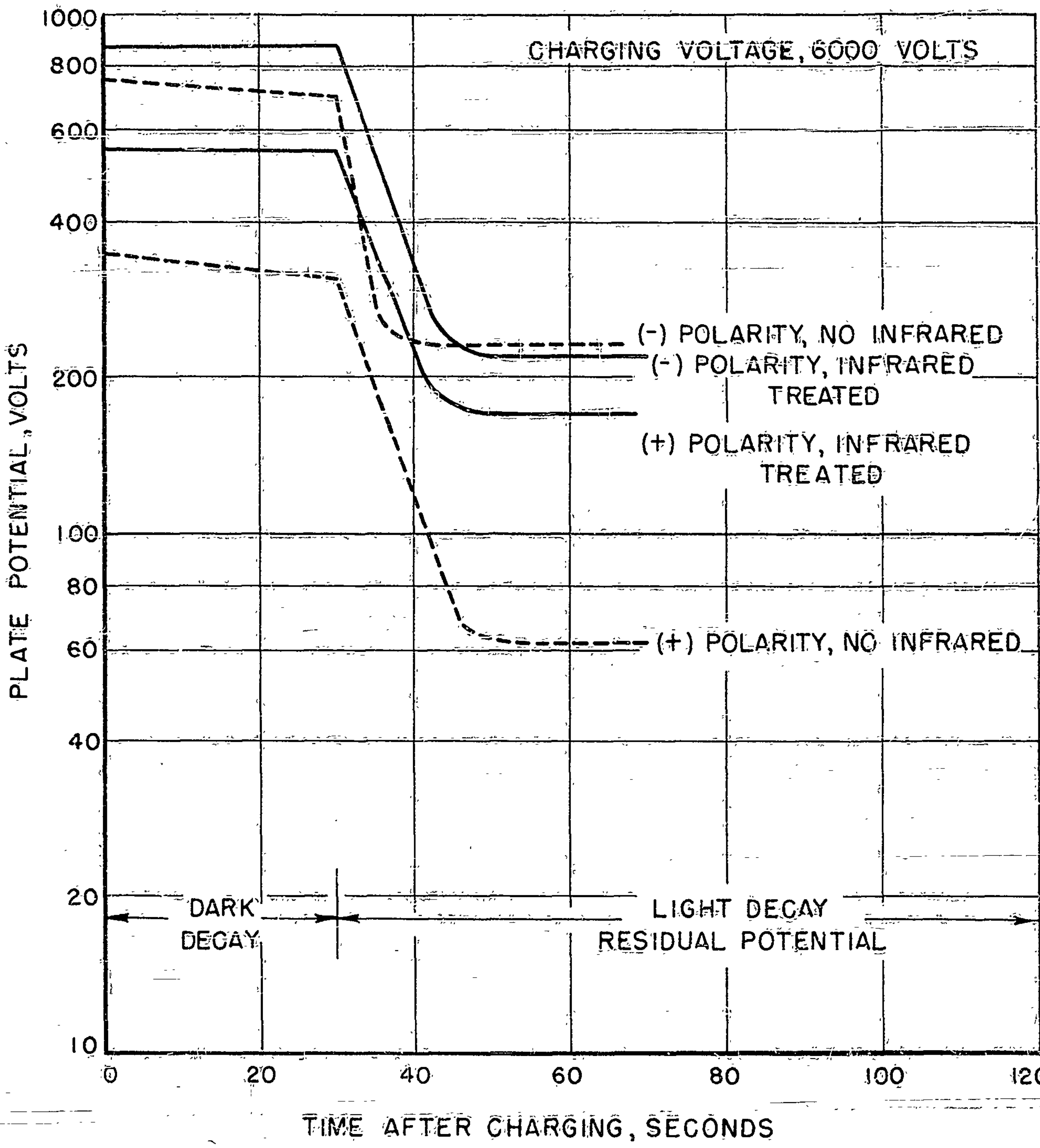

FIGURE 183. POTENTIAL-DECAY CHARACTERISTICS FOR DIP-COATED, PHOSPHOR PLATE, F-2039, 0.0145 INCH THICK

0-14761

of polarity and treatment. In the case of 1200 phosphor, the light decay is faster for negative polarity and for non infrared-treated plates.

The electrical properties are the same whether the plates are prepared by dipping or spraying, and curves which are typical of both are shown in Figure 179. Photographs made from plates prepared by those two methods did not show any advantage of one method over the other. Since the dipping process is more economical, this method of preparing phosphor plates will be used in the future. Also, the phosphor thickness can be held to close tolerances by controlling the withdrawal rate of the plate from the phosphor solution.

From the graphs shown in Figures 180 to 183, inclusive, it can be seen that the maximum potential of the plate increases when the thickness of the phosphor increases from 0.0035 inch to 0.007 inch. When the thickness increases beyond 0.007 inch, no significant change in accepted potential is observed. It can also be observed that the 2225 phosphor, even though approximately an order of magnitude slower in light decay, has, at a thickness of 0.0035 inch, the equivalent electrical properties of the F-2039 phosphor at a thickness of 0.007 inch.

In Table 46, the particle size of the various phosphors tested is listed. Table 47 lists the conditions under which the plates were developed and printed.

Particle size apparently is a very important factor in determining the graininess of images made with these phosphors. A strict comparison cannot be made on the basis of data presented here since the series of plates which is used to show the effect of particle size on graininess includes different types of phosphors as well. However, Figure 184 shows four pictures which illustrate the effect of particle size, and it is apparent that a decrease in particle size from 75 microns to about five microns brings with it a decrease in graininess. Although the electrical properties of the plate made using the ball-milled F-2039 phosphor were altered considerably in the process of milling, the photograph made from that plate also showed improved grain quality. Its grain is comparable to the picture made with the 2225 phosphor plate (particle size 0.5 to 5.0 microns).

An increase in thickness of the phosphor coating improves the tone quality up to a thickness of 0.007 inch. Beyond this thickness, the quality shows no further improvement. Pictures made from four plates, each having a different phosphor-layer thickness, are shown in Figure 185. These pictures illustrate this improvement of tone with thickness. A correlation between maximum accepted potential and image quality exists, in that, for thicknesses up to 0.007 inch, an increase in thickness increases both accepted potential and improves image quality. Above 0.007 inch in thickness, no improvement in either is noted.

Polishing the surface of a phosphor coating in no way improves the tone quality or graininess. This indicates that these characteristics are not affected by the smoothness of the phosphor surface. Preliminary tests on reducing the background have been made by using a potential on the development grid. These tests have shown enough promise to justify further investigation.

PHOSPHOR 1200
PARTICLE SIZE,
ABOVE 75 MICRONS

PHOSPHOR F-2039
PARTICLE SIZE,
5 TO 50 MICRONS

PHOSPHOR 2225
PARTICLE SIZE,
0.5 TO 5.0 MICRONS

PHOSPHOR F-2039
PARTICLE SIZE,
0.5 TO 5.0 MICRONS

FIGURE 184. EFFECT OF PHOSPHOR PARTICLE SIZE ON GRAININESS OF IMAGE

68468

THICKNESS, 0.0035 INCH

THICKNESS, 0.007 INCH

THICKNESS, 0.011 INCH

THICKNESS, 0.0145 INCH

FIGURE 185. EFFECT OF THICKNESS OF PHOSPHOR LAYER ON IMAGE QUALITY, PHOSPHOR F-2039

68469

The results of the experimental work to date may be summarized as follows:

(1) The 2225 phosphor is the best phosphor tested to date for photographic use.

(2) The F-2039 phosphor might prove to be a better phosphor than the 2225, since it has a considerably faster light decay, provided it could be produced in a smaller particle size (0.5 to 5.0 microns).

(3) The electrical properties and particle size of a phosphor are direct indications of the tone quality and graininess that can be expected in a photograph.

(4) The tone quality and graininess are not dependent upon the smoothness of the phosphor surface.

Insofar as further work on phosphors is concerned, the following should be considered:

(1) Elimination of background

(2) Further study on the effect of particle size

(3) Establish tests for studying such properties of these phosphors, as spectral sensitivity, optical absorption, and conductivity

(4) Determine the effect of using a potential-control grid in charging these plates

(5) Improve present test equipment to increase the accuracy of the data.

(Data for this report are recorded in Laboratory Record Books:

No. 4130, pages 34 - 76, inclusive.
No. 4388, pages 66 - 100, inclusive.
No. 4872, pages 34 - 80, inclusive.
No. 4946, pages 19 - 28, inclusive.
No. 5003, pages 1 - 39, inclusive.
No. 5005, pages 1 - 88, inclusive.
No. 5109, pages 1 - 16, inclusive.)

RMS/DTW/LEW:swr
March 9, 1950

APPENDIX

Engineering Information for Design of Electrophotographic Camera as Given in a Letter to Dr. Dessauer of The Haloid Company

APPENDIX

Engineering Information for Design of Electrophotographic Camera as Given in a Letter to Dr. Dessauer of The Haloid Company

February 2, 1950

Dr. John Dessauer
The Haloid Company
Rochester 3, New York

Dear Dr. Dessauer:

The following recommendations for the basic data on which to construct a camera for the Signal Corps project are made in compliance with your letter of January 5, 1950, addressed to Dr. Schaffert.

These recommendations are the best that can be made in the light of present information. It is the consensus of the group working on this project that these conditions represent those which will produce pictures of quality equivalent to the best that have been produced in the laboratory. Recommendations are based on the over-all camera design already accepted by The Haloid Company.

In some cases it has been suggested that a certain amount of flexibility be incorporated in the camera design to allow for later adjustments. It is also to be understood that work after this date may change some of the actual process steps so that better results may be obtained as the result of future work. Such alterations are not expected to change any fundamental design elements of the camera, but they may lead to the future recommendation that certain minor features in the camera be modified, for example, the nature of the brush which generates the powder cloud, or the developer powders to be used with the camera.

No specific recommendations are being made on the construction of the power supply, as it was agreed some time ago that your company was to work out this aspect of the camera design.

In making recommendations, every attempt has been made to leave as much freedom as possible for your design efforts. For this reason, nothing is said as to exactly how the mechanical features of the camera shall be constructed. We have attempted to set down only the fundamental details of the process to be carried out.

Plate Backing Material. The backing material to be used is Gem Metal brass (General Plate Makers Supply Company, 522 South Clinton Street, Chicago 7, Illinois) with a highly polished and buffed surface (as photoengravers' brass). Metal thickness of 0.064 inch has been used and can be recommended. Thinner brass may be used, but the thickness must be such that selenium will not crack off of the metal during handling and such that adhesive transfer will not bend the plate or crack off selenium. Minimum thickness has not been established.

Preparation of Metal Backing-Plate Surface. The metal surface is to be cleaned by scrubbing with a cotton swab wet with Gold Seal Glass Wax, polished with a dry cotton swab to remove Glass Wax residue, washed with synthetic detergent (Dupanol), rinsed thoroughly with tap water and immediately rinsed with methyl alcohol (commercial). The plates are then immediately dipped into a vapor-degreasing bath containing boiling isopropyl alcohol. After this they are placed immediately in the vacuum chamber.

Great care must be exercised in the preparation of the plates for selenium evaporation. Certainly fingers or other objects must not be allowed to touch the plate after the cleaning process has started. The above description includes all of the obvious steps in the process as it is carried out in the laboratory. However, there may be some unobvious techniques which will have to be discovered by trial and error.

Selenium. The selenium to be used is Canadian Copper Refiners ARQ brand, C.P., shotted.

Plate Temperature During Evaporation. The plates are to be fastened on a metal platen held between 70 and 74°C. during the actual evaporation process. Plates must be fastened securely to the platen so that good contact is assured over the back of the plate.

Evaporation of Selenium. Selenium is to be evaporated from suitable boats so that the entire charge of material will be evaporated in approximately twelve minutes (molybdenum boats are used in the laboratory). The charge of selenium is to be determined so that plate with a uniform coating of selenium, between 50 and 55 microns thick, will result. Pressure in the evaporating chambershould be below 0.5 micron before the selenium is heated.

Variations of selenium thickness over a single plate should not exceed plus or minus one micron.

The plate should be reduced to room temperature within two minutes of the end of the evaporation cycle. Removal of the plate from heated platen within two minutes is sufficient to fulfill this requirement.

Power Supply. The power supply should furnish a total D.C. voltage sufficient to provide all of the voltages required by the process. The voltage output, which will be in the neighborhood of 7,000 volts, should not vary more than plus or minus 100 volts, or an adjustment should be provided so that the operator can adjust the output voltage to this range.

Lower-voltage taps should be provided for the potential-control grid of the sensitizing unit and for the development grid.

Voltages on the potential-control grid should be held to within plus or minus six volts and relatively simple means should be provided for selecting values for this voltage from -100 to +300 volts. The control for this voltage should be available to the camera operator.

Voltage on the development grid should be available from -50 to +200 volts. This voltage will be delivered to potentiometers to be described under a separate section.

Plate-Sensitizing Unit. The plate-sensitizing unit recommended is that designed and made by The Haloid Company. This unit has been supplied to Battelle for experimental use and it is understood that The Haloid Company can carry out the adaptation of this unit to the Signal Corps camera.

The potential on the corona wires should be 6400 plus or minus 90 volts.

The spacing between the potential-control grid and the plate surface should be 3/16, plus or minus 0.015 inch (±0.005" over any plate).

The travel of the charging unit over the plate should be one inch, plus or minus 0.2 inch per second (±0.05" for motion over one plate).

The charging unit should move far enough on each end of its stroke so that its center line moves one inch past the edge of the selenium area which is being sensitized.

The final plate potential should not exceed 275 volts. The potential to which the plates are sensitized should be plus or minus 4 per cent of the potential selected for any given set of conditions.

As to the potential on the potential-control grid; it is recommended that a potentiometer be provided which will allow the adjustment of this potential to values between minus 100 and plus 180 volts. The potential on this element should be maintained so that it does not change more than 5 volts when the corona current is flowing to it from the corona-discharge wires.

The plate-sensitizing unit must be so constructed that the free (unsupported) length of the corona-discharge wires is one inch greater than the width of the selenium surface to be sensitized.

Plate Exposure. Plate exposure is to be made according to the indications of a photoelectric exposure meter of the conventional type. It is possible that further work will show that the reciprocity relationship does not hold for electrophotography well enough that the simple exposure-calculating scale on these meters can be used. In this case, the data will be supplied so that a modified exposure scale can be made for one of the conventional exposure meters.

It is understood that The Haloid Company is to supply the photographic lens and is to select this lens on the basis of Haloid's knowledge of the photographic process.

Time Period Between Sensitization and Development. It is recommended that the plate be sensitized immediately before exposure and that, in general, the plate be developed as quickly as possible after it is exposed. However, there will be occasions in which the plate will be sensitized and not exposed. It is recommended that, if a plate has been sensitized for longer than fifteen minutes, it be resensitized before it is exposed.

Before a plate is resensitized it should be exposed to light to remove the residual charge on its surface. For this purpose, it is suggested that a small bulb of approximately five watts input be mounted in the camera and arranged so as to expose all parts of the plate. A switch should be provided, possibly in the form of a push button, whereby this light can be turned on for about one second when it is necessary to resensitize a plate. After this exposure of the plate, the sensitizing process can be repeated. It is recommended that the plates not be resensitized at intervals less than five minutes. More frequent resensitization may lead to undesirable plate-fatigue effects.

It is recommended that a plate be developed within twenty minutesof the time it was sensitized. Thus, if fifteen minutes time has elapsed between sensitization and exposure, the plate should be developed within the next five minutes. If the plate was exposed five minutes after it was sensitized, then fifteen minutes may be allowed to pass before development.

Laboratory work on the time delays between sensitization and development have been such that it was impossible to establish any minimum times for this period. It is recognized, however, that it may be necessary to set a minimum time between plate sensitization and development. It is recommended that this minimum be set by experimentation on the final camera. Such minimum time intervals will not be greater than one minute, however.

Developer Box. The developer unit should consist of a brass box of internal dimensions approximately five by six by two and one-half inches. The bottom of this box is to be covered with 16-mesh bronze screen.

Brass is recommended for this box simply because it has been found satisfactory in laboratory models. It is likely that other metals would be equally satisfactory.

The powder cloud is produced by a horse-hair brush arranged to brush against the screen in the bottom of the box and to move over the entire width of the box. The brush may be hand or mechanically activated. Hand activation can be provided by extending a rod out of one side of the camera body. The brush is made of a continuous section of horse-hair bristles one inch long and approximately 1/8 inch thick at the base, or compressed section. The mounting of the bristles is optional and considerable variations in the brush may be satisfactory. It is recommended that the brush be mounted so that the pressure of the brush on the wire screen can be adjusted. The brush should extend the long dimension of the box, that is, with its motion across the narrow dimension of the box.

The actual nature of the cloud of powder produced in this type of powder-cloud developing box depends on how the air currents flow when the brush is activated. For this reason it may be desirable to add air baffle to the brush member. However, the exact nature of this baffle will have to be determined as the result of experiments on the camera itself.

It is recommended that elastic stops be placed to limit the motion of the brush to within 1/4 inch of the sides of the box. Banging of the brush against the sides of the box will produce large clouds of powder, but this effect should be eliminated because of its variability.

Means should be provided for draining out the entire charge of developer and for refilling the box with fresh developer after approximately twelve prints have been made.

A sliding cover must be provided to separate the development chamber from the exposure chamber of the camera when there is no plate in the developing position. It is recommended that this slide occupy the position which would be occupied by the plate during development so as to assure that no developer powder can enter the upper portions of the camera even if the camera is inverted and vibrated.

While it is not necessary, it is suggested that a shield be placed on the plate during the development of the plate. This shield would be so made that it restricts development to a limited area of the plate, for example, to a four-by-five-inch area in the present camera.

The development box should be provided with a five-point potentiometer arranged so that the switch arm will advance one point on the potentiometer for every two complete cycles of the brush. This potentiometer is to be arranged to control the potential of the development grid and the points should be arranged so that potentials of from minus 50 to plus 200 volts can be applied to the plate by inserting the proper resistors between the switch points. This switching arrangement may not be used in the first camera to be constructed, but it should be included to allow potential control of the grid if necessary. The voltages to be required on the steps of the potentiometer will be determined later.

In addition to the automatically operated potentiometer, a second potentiometer should be provided which can be used to adjust manually the potential on the development grid. This potentiometer should permit voltages to be applied to the grid from minus 50 to plus 50. This potentiometer is recommended for possible use in controlling the over-all density range on the final print even if it is not found desirable to cycle the potential on the development grid.

Practically no current is required by the development grid if it is properly insulated from the rest of the camera. For this reason the resistance involved in the potentiometers recommended may be very high, certainly in the megohm range.

Developer. The developer will consist of plain beads and a resinous powder in the proportions of twelve to one by weight, respectively.

The glass beads are 30 on 50 screen fraction. (Type 8 of the Minnesota Mining and Manufacturing Company.)

The use of plain glass beads is recommended at this time, but future work may change the situation so that some other carrier will be found which has important advantages. The change to other carriers will involve no important changes in the camera design.

The recommended developer powder will be composed of 95 per cent Amberol F-71 (Resinous Products and Chemical Company) and 5 per cent (by weight) Pigment Deep Black, Extra Concentrated PV (General Analine and Chemical Company). In preparation, the ingredients are fused together and dispersed on a rubber mill. The cooled residue is then micreatomized to an average particle size of three microns.

In case The Haloid Company is not in a position to manufacture developer powder for fulfilling the Signal Corps contract, Battelle will be in a position to manufacture and deliver small but adequate amounts of developer powder for demonstrating the camera.

Developer is to be added to the developing box as a final adjustment based on the performance of the camera. Approximately sixty grams is recommended for test. This quantity of developer will process twelve plates without serious changes in density of the final image. At the end of twelve prints, it is recommended that the developer be discharged and new developer added. As an alternative procedure, it may be possible to retone the developer, but a retoning procedure is not fixed as this time.

The quantity of developer to be used can be determined volumetrically and might be provided in small, disposable envelopes.

Developer Grid. The development grid should be constructed of approximately 0.0035-inch diameter, stainless-steel wire (wire-recorder wire). The grid should have sixty wires per inch and should be so constructed that the wires extend in the direction of motion of the brush. The grid should be so constructed that the wires remain taut in the camera.

The grid should be mounted so that the plane of the wires is flush with the top edge of the developer box. A construction of grid which has been found satisfactory involves a rectangular frame made of 1/8-inch by 1/2-inch angle iron mounted within the confines of the developer box. This produces an actual grid area four by five inches.

A grid-to-plate spacing of 0.080, plus or minus 0.010 inch, is recommended with the grid stationary with respect to the plate during development. It is suggested that the grid be so mounted that it can be adjusted, in the final camera, from 0.040 to 0.080 inch grid-to-plate spacing.

The development grid must be electrically insulated from the developer box and other metal parts of the camera so that potentials up to 400 volts can be applied to the grid. (A 200-volt safety factor is included in this figure.)

The development grid must be wiped clean after each picture has been developed. It is recommended that this cleaning be done by pushing over the grid a device consisting of small felt pads clamped onto the wires and possibly guided on the sides of the development box. It is recognized that only a small space exists above the development grid for the upper portion of this wiping device.

Plate Development. After the plate is moved into the developing position, immediately above the development grid, development is effected by manually moving the rod connected to the brush in the development box. The rod should be moved smoothly back and forth over the entire extent of the box (except for 1/4-inch clearance at each end) to obtain full length of stroke.

The complete development of a plate should consist of 40 to 60 cycles of the rod, that is, 80 to 120 passages of the brush over the screen in the bottom of the developer box. The developing time should be 20 to 30 seconds, that is, two cycles per second.

During the development process, the box should be held so that the plate being developed is essentially horizontal. Limits of departure from the horizontal position will be determined later.

The above specifications for development are the best that can be made at this time. However, the whole development process will receive major attention in the remaining portion of the project and it is hoped that improvements will be made before the delivery of the camera.

Transfer Material. The best recommendation that can be made at the present time for the transfer tape is Minnesota Mining and Manufacturing Company Tape No. 700, White. This tape is made with a white cellulose acetate fiber backing. It has been used to make satisfactory transfers in the laboratory. Tape No. 700 requires about five pounds force to pull it off of the original roll in widths usable in a camera and it has more tack than is required for the transfer of the powder image. Under pressures required to pull it off the roll, it is expected to stretch less than one per cent.

While this tape is recommended at the present time, a major effort will be made to improve this particular tape or to obtain a more satisfactory tape before the camera is finished. Specifically, a tape having less tack and one which can be more easily pulled off of the supply roll will be sought. The Minnesota Mining and Manufacturing Company has promised samples of tapes which may be more desirable, and efforts will be made to reduce the unrolling force required on the No. 700 tape by treatment of the back surface of the tape or by the interposition of a separate release sheet.

Adhesive Transfer. Transfer of the image from the plate to a final surface should be done by means of a white, opaque adhesive tape. In the camera, the tape should be unrolled and passed over an elastic ball-bearing roller in contact with the image surface of the plate. This roller should have an outside diameter of one inch, the outer three-sixteenths of which consists of a rubber material having a rubber Durometer Rubber Hardness of 75 to 80 (Rex Gauge). This roller should press against the plate with a force of 200 pounds. This force should be applied only when a transfer is actually being made.

It is recommended that the plate be backed up during transfer by a roller having the same specifications as above. This recommendation is made because of the possibility of bending the plate during transfer with other arrangements.

Transfer should be done at less than one inch per second.

The means of delivering the tape to the transfer roller and of propelling the plate and tape through the transfer operation are left to the judgment of the camera designer.

Means should be provided for removing and disposing of a nonadhesive interleaf from the original roll of adhesive-transfer material if such an interleaf is found desirable in later research.

Fixing Material. The best recommendation that can be made at the present time for the fixing tape is Minnesota Mining and Manufacturing Tape No. 800. This tape is transparent to a degree sufficient for the purpose and requires small forces to pull it off the supply roll.

Attempts will be made to find or develop other tapes for this purpose before the completion of the camera, but this tape is believed to be satisfactory.

Adhesive Fixing. The image is to be fixed onto the adhesive-transfer material by the imposition of a transparent adhesive tape. This tape should be pulled off the supply roll in the camera, passed over a pressure roller and impressed onto the transfer tape.

The roller used to impose the fixing tape should be of the same construction as the transfer roller, and press against the tape with a force of 200 pounds.

The means of delivering the tape to the transfer roller and of propelling the plate and tape through the fixing operation are left to the judgment of the camera designer. It is suggested that consideration be given to the use of a drive roller, possibly coated with silicone resin, and to the possibility of activating the entire transfer and fixing operation by the force exerted on the tape as the picture is pulled out of the camera.

Means should be provided for removing and disposing of a non-adhesive interleaf from the original roll of adhesive-fixing material, if such an interleaf is found desirable in later research.

Plate Cleaning. It is recommended that a small unit be constructed for cleaning used plates in a granular material. This device may involve either the rocking-tray or the plunge type of cleaning. The fundamentals of these two types of cleaning are so well known that they need no further description.

The construction of the cleaning unit is left to the camera designer as is the question as to whether it should be a part of the camera, a part of the power supply, or a separate unit.

It will be necessary after the cleaning with a granular material, to wipe the plate with a cotton pad, or a small, soft brush and it may be necessary to supply a small brush for removing residual cleaning material from the metal head at the edges of the plate.

After the plate has been used five times, it should be washed with ethyl alcohol and allowed to dry before reuse.

General Recommendations. It is recommended that desiccant cartridges be mounted in the main body of the camera and in the developing chamber so that the humidity within them can be kept low regardless of the humidity of the air in which the camera is used.

Very truly yours,

(Signed) Lewis E. Walkup

Lewis E. Walkup
Assistant Supervisor
Graphic Arts Research Division

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AD-A800 024

Battelle Memorial Inst., Columbus, Ohio

CONTINUOUS-TONE ELECTROSTATIC ELECTROGRAPHY, by R.M. Schaffert, D.T. Williams, and L.E. Walkup. Quarterly progress rept. no. 7, 15 Dec 49-15 Mar 50. [84]p. incl. illus. tables. (Contract W-36-039-sc-36851)

DIV: Photography & Other Reproduction Processes (24)

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